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# Relation of Cultural Practices to Winter Wheat Production, Southern Great Plains Field Station, Woodward, Okla.



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Agriculture, Bureau of Plant Industry, Soils,  
and Agricultural Engineering, Agricultural  
Research Administration

In cooperation with the Oklahoma Agricultural Experiment Station

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United States Department of Agriculture, Agricultural Research Administration, Bureau of Plant Industry, Soils, and Agricultural Engineering, in cooperation with the Oklahoma Agricultural Experiment Station

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Winter wheat is the most important crop in western Oklahoma and the adjacent sections of other States, the area represented by the Southern Great Plains Field Station. There wheat occupies a larger acreage than do all other annual crops combined. It is the principal crop on most of the silt loam and fine sandy loam soils. It is important also on the very fine sandy loams and loamy fine sands, although on these soils it competes with sorghums and with cotton in

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the southern part of the section. Wheat is grown to some extent on soils too sandy for safe wheat culture. The potential capacity for yield is generally low on such soils, but this is partly compensated by less frequent severe injury from drought.

Studies on cultural practices were undertaken to determine the best tillage methods, crop sequences, and fertility practices for wheat in this region. The principal objectives of these experiments were:

(1) To evaluate the effect of different implements and different times of seedbed preparation on the productiveness of wheat on land planted to wheat each year and to determine the effect of methods of preparing fallow land on the productiveness of wheat.

(2) To determine the effect on yield of different types of drills used at two different dates on seedbeds prepared by different methods.

(3) To determine the productiveness of wheat following different row crops and to compare normal spacings of row crops with wide-row spacings as preparations for wheat.

(4) To compare the productiveness of wheat alternately fallowed and cropped or fallowed once in 3, 4, or 5 years, with productiveness on land cropped to wheat each year.

(5) To determine the effect of organic amendments, legumes, and hay crops on the yield of wheat in rotations and to measure the effect of commercial fertilizers on the yield of wheat.

## CLIMATIC CONDITIONS

Crop production in the dry-land area is determined chiefly by climatic factors. The five that have been measured at the Woodward station are precipitation, evaporation, temperature, wind velocity, and relative humidity.

### PRECIPITATION

Rainfall is the most important single climatic factor in this area. The amount and distribution of the precipitation determine the quantity of water that will be available to crops at critical periods in their growth. (Crop growth, even in years when the total precipitation is above average, is almost always limited by lack of water at some period. Both total quantity and distribution of rainfall vary extremely.

The average annual precipitation from 1915 through 1948 was 23.76 inches (table 1). The departures from the average are shown in figure 1. This also illustrates the prolonged period of below-average precipitation that brought about the acute "dust bowl" conditions of the early thirties. The extreme range was from 14.79 inches in 1933 to 41.22 inches in 1941. The detailed monthly precipitation is given in table 22, Appendix.

The distribution of rainfall varies from year to year, but the general trend is for the rainfall to be low in July in comparison with the months immediately preceding and following it (fig. 2). This drop in July rainfall explains why row crops, such as sorghums, do best when planted late enough so that they make the major part of their growth

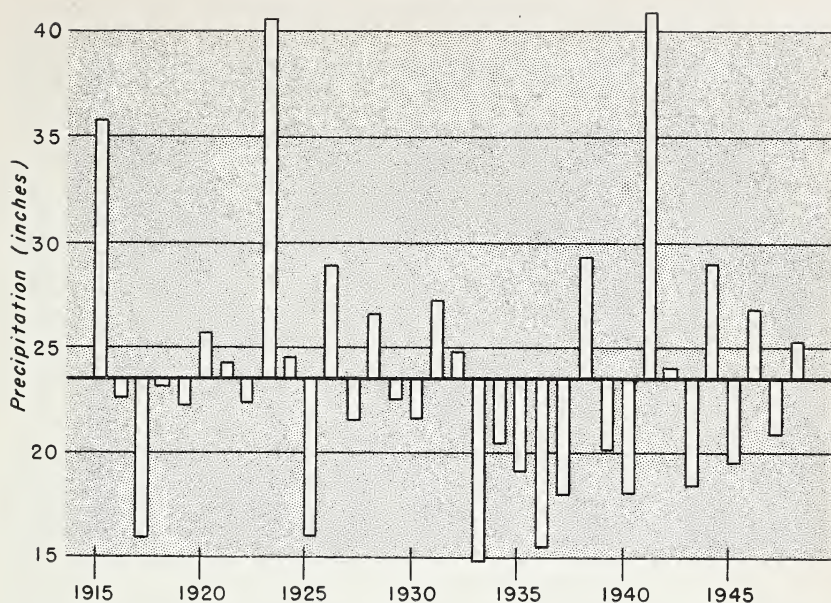


FIGURE 1.—Departures of annual precipitation from the 34-year average (23.76 in.), Woodward, Okla., 1915–48.

later in the season. The precipitation is also relatively low during the winter months. The average precipitation for each of the months, December through February, 1915–48, was less than an inch. Therefore, abundant fall moisture is necessary to establish small grains and to carry them through the winter.

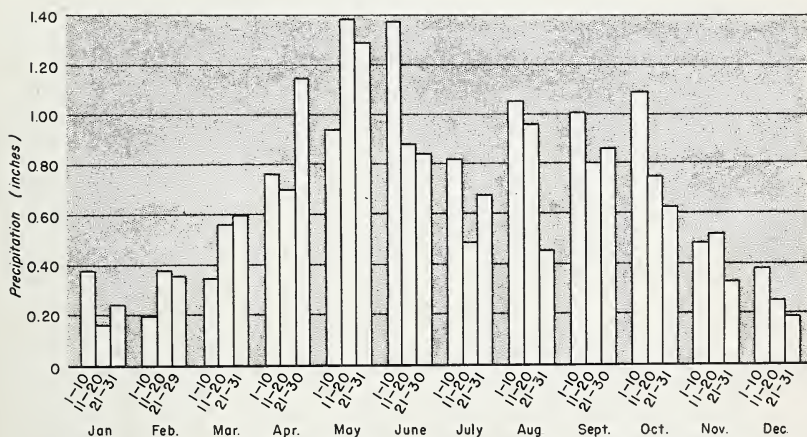


FIGURE 2.—Average precipitation by 10-day periods (average of 34 years' records), Woodward, Okla., 1915–48.

TABLE 1.—*Monthly, total or average, and annual precipitation, mean temperature, wind velocity, evaporation, and relative humidity, Southern Great Plains Field Station, Woodward, Okla., 1915-48*

Item	Jan.	Feb.	Mar.	Apr.	May	June	July
Precipitation-----inches--	0. 74	0. 89	1. 46	2. 55	3. 52	3. 02	1. 95
Mean temperature degrees F--	34	39	47	57	66	77	82
Wind velocity miles per hour--	7. 0	7. 9	9. 0	8. 8	7. 2	7. 2	6. 6
Evaporation-----inches--				6. 21	7. 43	9. 37	10. 89
Relative humidity--percent--				55. 0	58. 9	56. 3	51. 2
Item	Aug.	Sept.	Oct.	Nov.	Dec.	Sea- sonal total or av- erage, Apr.- Sept.	An- nual total or av- erage
Precipitation-----inches--	2. 41	2. 64	2. 44	1. 32	0. 82	16. 09	23. 76
Mean temperature degrees F--	81	72	60	46	36	73	58
Wind velocity miles per hour--	6. 2	7. 0	6. 6	6. 9	6. 8	7. 2	7. 3
Evaporation-----inches--	9. 86	7. 52				51. 28	
Relative humidity--percent--	53. 0	56. 8				55. 20	

### EVAPORATION

Evaporation is important in determining crop production, in that it is a measure of the demand for water by crops. The quantity of water evaporated in a day depends chiefly on the saturation deficit of the air and on wind velocity. It is to a considerable extent complementary with precipitation in that frequent rains, which keep the moisture content of the air high, reduce the evaporation.

The average evaporation by months is shown in table 1. The average for the 6-month period, April through September, was 51.28 inches. The highest was 61.70 in 1934; the lowest, 41.67 inches in 1915 (table 23, Appendix).

### TEMPERATURES

Maximum and minimum daily temperatures are perhaps more important than mean temperatures in crop production, as they represent the extremes to which crops may be subjected. Excessively high summer temperatures may ruin a crop when it is running short of water. Abnormally cold temperatures in winter or early spring may cause winter injury. During the period covered by these experiments, no killing of wheat caused by low winter or spring temperatures has been observed, except in seasons when the wheat had been weakened

by other causes. On the average, however, summer mean temperatures are a fair measure of climate, because mean temperatures are usually high when precipitation is low and vice versa (table 1; table 24, Appendix).

### WIND VELOCITY

Highest average wind velocities in this region occur during March and April, and the lowest in August (table 1). High velocities for short periods, which are not reflected in general averages, are more important than mean velocities in determining if crops are injured either by direct injury during torrential storms or by soil blowing. Mean wind velocities by months and years are given in table 25, Appendix.

### RELATIVE HUMIDITY

Relative humidity is closely related to temperature and rainfall (table 1).

Relationships between some of the principal climatic factors and crop yields are discussed later.

## EXPERIMENTAL PROCEDURE

### DESCRIPTION OF EXPERIMENTAL FIELDS

Most of the experiments at Woodward have been conducted on two fields, designated herein as fields A and B. The two fields differ substantially in soil type and in their presumed adaptation to wheat.

The soil in field A consists chiefly of Pratt fine sandy loam and Pratt loamy fine sand. An erosion survey describes this soil as having a high infiltration rate. Recent tests, however, indicate that at least parts of the field are much more slowly permeable than had heretofore been supposed. The topography in this field is slightly rolling.

Different parts of the field differ in productivity, and care was taken to restrict comparisons to comparable areas. The surface soil has a variable texture, which is shown best by a range in the moisture equivalent from a little more than 6 to a maximum of 12 percent. The majority of the plots have a moisture equivalent of less than 10 percent. Generally, there is little change in texture with depth.

The field was broken out from native sod in January 1914, and the first crops were grown on uniformly prepared land that year. The field was divided into plots for experimental culture practices and sequence treatments in 1914.

Most of the soil in field B is similar to Grant silt loam, with small areas occupied by Pratt fine sandy loam and Weymouth very fine sandy loam. A small area used occasionally for plots was of Pratt loamy fine sand.

The field has a general slope to the northeast; and the slope of most of the experimental area is from 1 to 3 percent. An erosion survey indicates that the more level part of the field has suffered slight sheet erosion. A small area of the field has slopes up to 6 percent and has

undergone moderate sheet erosion. This part cannot be compared fairly with the rest of the field. In the year of uniform cropping before experimental work was started, however, yields from the steeper parts of the field compared favorably with those from less sloping land.

The texture of the soil is shown by moisture equivalent determinations on a number of the plots. Moisture equivalents of the surface foot of soil ranged from 11.25 to 12.25 percent. Soils below the surface foot were generally heavier, the moisture equivalents ranging as high as 16 percent.

The field was partly in native grass pasture and partly in cropped land when the tract was acquired. In some years there was a marked difference in the early spring color of wheat on the two parts of the field. In many years there was no discernible difference. With a few exceptions, the experiments were laid out so that comparable practices were conducted on relatively uniform land.

### PLOT SIZE AND ARRANGEMENT

The size of the field plots was 2 by 8 rods, or one-tenth acre. Plots were separated at the sides by  $3\frac{2}{3}$ -foot alleys and at the ends by 20-foot roads. In later years the alleys were widened to permit harvesting with a combine and the sizes of the plots were reduced to 0.095 acre. Some special experiments, principally those with fertilizers, were on smaller plots.

Each cropping system or rotation was represented by as many plots as there were years in the system; thus, each crop and each tillage method was represented each year. Most rotations were laid out in blocks.

Cropping methods, except in the fertilizer experiment, were not directly replicated. There were enough treatments of a similar nature, however, so that most treatments were substantially if not exactly repeated.

### TILLAGE AND SEEDING

Initial tillage treatments that were comparable as to time were generally performed on the same day. With all tests using various implements extreme care was taken to eliminate as nearly as possible all variables other than the tillage.

Early tillage refers to cultivation as soon as practicable after wheat was harvested. This was usually in late June or early July and averaged July 6. Midseason tillage was performed on or about August 15. Late tillage was done September 15 or shortly thereafter. At first a distinction was made between September 15 tillage and that performed at seeding, but this distinction was not important, as seeding was usually done as soon after the late-fall cultivation as conditions permitted.

All plots in a given crop were planted to the same variety on the same date by the same method, except when a particular practice called for a deviation in date or method. The varieties used were those considered standard for the area and were changed only when

another variety had become better established. For example, the varieties of wheat used during the period were Turkey or Kanred 1915-34, Cheyenne 1935-45, and Pawnee 1946-48.

In field B, 21 plots, in addition to checks, were used for continuous-tillage tests. The methods differ in the tillage implement used, the time seedbed preparation was started, and in such details as binding rather than combining the crop, burning of stubble, and the application of manure. When the experiment was outlined, it was hoped that general comparisons could be made. It soon became evident, however, that, because of soil variability, comparisons must be restricted to relatively small groups of plots.

### STATISTICAL EVALUATION OF YIELD DATA

The plot lay-outs made for one field in 1914 (field A) and the other in 1932 (field B) were not set up with complete statistical analysis in mind. Rather, they were grouped for convenience in handling by crops, rotations, or treatments. Owing to the soil variations, many of the treatments had to be compared only with nearby plots. Confirmations of data were obtained by cropping through several years rather than by replication of plots, rotations, tillage methods, and cultural practices in any one year. Accordingly, it is not possible to separate the variation caused by soil from that caused by treatment.

Most yield data were subjected to analysis of variance, and the treatment-by-years interaction was used as a measure of experimental error. The least significant differences (L. S. D.) for comparing treatments or tillage practices were based on this error term.

## RESULTS

### CONTINUOUS WHEAT PRODUCTION AS AFFECTED BY TILLAGE PRACTICES

Wheat was grown continuously on land prepared early, midseason, and late, with various implements, including the moldboard plow, one-way disk plow (hereafter called one-way), lister, disk, and with subsurface tillage. Wheat was also "stubbled-in" with no preparation. A few plots were seeded a month later than the rest of the field.

#### EFFECT OF TIME AND TYPE OF TILLAGE WHEN USED CONTINUOUSLY

A small number of the tillage studies were made in field A. The first study consisted of two methods on early-prepared land compared with one method on late-prepared land. Additional methods were introduced a few years later. Yields of wheat in table 2 are for the period that all methods were in use (table 26, Appendix). Yields of rye for like tillage practices are included in table 2 for comparison. These indicate that rye responds to time of tillage in the same manner as wheat.

TABLE 2.—*Yields of winter wheat and winter rye under 6 tillage methods of continuous production, field A, Woodward, Okla.*

Time, <sup>1</sup> type, and depth of tillage	Average acre yields <sup>2</sup>	
	Winter wheat, 1922-48	Winter rye, 1920-48
	<i>Bushels</i>	<i>Bushels</i>
Plowed early, 8 inches .....	17. 8	12. 3
Listed early .....	16. 8	10. 9
Plowed early, 4 inches .....	20. 0	14. 4
Early disked or one-wayed .....	18. 3	12. 0
Plowed late .....	10. 9	6. 5
One-wayed late .....	11. 6	9. 1

<sup>1</sup> Average date for early tillage, July 6; average date for late tillage, September 29.

<sup>2</sup> Significant at 5-percent level compared with early plowing at 8-inch depth = 2.0 bu. for wheat; 1.4 bu. for rye.

Using the deep early-plowed method as the standard practice, only the early 4-inch plowing was significantly better by a narrow margin. Growth and yields on late plowing and late one-waying were much lower than the standard (fig. 3 and table 26, Appendix).



FIGURE 3.—Late-plowed plot on left and early-plowed on right, showing difference in stand and growth in the spring after a dry fall when plants did not become properly rooted until mid-January.



FIGURE 4.—Plants from (A) late-plowed, (B) early-plowed, and (C) fallowed plots, showing difference in development at the end of November in a dry fall (0.27-inch precipitation from planting October 8 to November 27).

During the period early preparation varied from June 18 to July 26 and averaged July 6. Late preparation ranged from August 30 to November 9, but averaged September 29. Differences in top development of wheat seedlings are accompanied by differences in root growth (fig. 4). Yields from these plots were 5.3 bushels per acre for late plowing, 19.5 bushels for early plowing, and 19.7 bushels from fallowed plot.

Results from the continuous tillage methods in field B are shown in table 3. The data are divided into groups, and because of differences in the productivity of the soil on which these tests were located, comparisons are valid only when made within groups.

Burning late and then one-waying was included in group 2. This treatment proved to be impossible to do as outlined. Burning after harvest can be performed easily, but by September 15 the growth of green weeds usually prevented natural burning. In this instance it was performed by sprinkling the plot with combustible material or by using a weed burner.

The comparison of early plowing with early chiseling, or duckfooting, given for group 3, runs for a shorter period of years than the other comparisons, because duckfooting was replaced by another method of tillage in 1941. The low yields are a reflection of the level of wheat production during the period covered by the comparison. For the whole period (1933-48) the plowed plot produced an average of 19.1 bushels to the acre.

The listing in group 4 cannot be compared fairly with the deep and shallow plowing in group 1, because it was located on land of lower productivity.

TABLE 3.—*Average yields of continuous wheat separated into comparable tillage groups, on land where the same cultural practice was followed each year on the same plot, field B, Woodward, Okla., 1933-48*

Plot group, <sup>1</sup> cultural practice, and depth	Acre yield
<i>Group 1</i>	<i>Bushels</i>
Plowed early, 8 inches.....	19. 1
Plowed midseason, 8 inches.....	17. 1
Plowed early, 4 inches.....	20. 3
Plowed midseason, 4 inches.....	17. 8
Plowed late, 4 inches.....	14. 0
L. S. D. at 5-percent level.....	1. 7
<i>Group 2</i>	
Plowed early, 8 inches.....	17. 9
Plowed early, 8 inches; burned stubble.....	17. 8
Plowed early, 8 inches; top-dressed with manure.....	18. 0
Burned and one-wayed late.....	13. 2
L. S. D. at 5-percent level.....	2. 0
<i>Group 3<sup>2</sup></i>	
Plowed early, 8 inches.....	13. 1
Chiseled or duckfooted early.....	12. 7
<i>Group 4</i>	
Listed early.....	16. 9
Listed midseason.....	12. 9
No preparation, seed stubbled-in.....	6. 7
L. S. D. at 5-percent level.....	2. 9
<i>Group 5</i>	
One-wayed early; crop binder-harvested.....	13. 5
Plowed early, 8 inches; crop binder-harvested.....	13. 7
Plowed late, 4 inches; crop binder-harvested.....	7. 2
Double-disked early; cultivated with disk (crop combine-harvested).....	14. 0
L. S. D. at 5-percent level.....	1. 8
<i>Group 6</i>	
One-wayed early.....	19. 2
One-wayed late.....	12. 2
L. S. D. at 5-percent level.....	2. 0

<sup>1</sup> The field was divided into comparable tillage groups.

<sup>2</sup> Experiment ended in 1940 (p. 9).

Group 5 includes all the binder-harvested plots in the continuous-cropping series. The combine harvester-thresher had come into general use at the time these experiments were started, but there was still the fear that leaving the heavy combine stubble on the land might result in lowered yields, particularly in dry years or if tillage was performed late. Consequently, a few binder-harvested plots were introduced into the experiment for comparison. Unfortunately, they were all located on the least productive soil in the experiment and could be compared with only one other method, namely, disking.

There was no evidence that use of a binder was preferable, even in dry years.

Few direct comparisons between different tillage implements could be made from the results of the continuous-tillage treatments, and such comparisons, when tillage was started at the same time, were all within the limits of experimental error. More comparisons between times of tillage were feasible, and differences caused by time of tillage were generally highly significant. Losses in yield resulting from the time of starting tillage treatments were serious and could not be corrected by any kind of cultivation performed at a later date.

#### BORDERED OR DIKED SOIL AREAS

A single plot in field B on land with a gentle slope was leveled and provided with a raised border to prevent all runoff. This was done to determine whether the yield of wheat would be materially increased if all loss of water through runoff was prevented. This plot was continuously one-wayed. The adjacent plot to which it can best be compared was alternately one-wayed and plowed. Each of these plots exceeded the other in yield an equal number of times during the 14-year period that the experiment was in progress. The average difference was only 0.7 bushel, and that difference was in favor of the nonbordered plot. Holding all the water on the land may be beneficial in some years and harmful in others.

#### USE OF SPECIAL AND STANDARD TILLAGE PRACTICES IN ALTERNATE YEARS

The preceding section discussed tillage experiments conducted continuously on the same plots. This section covers experiments where treatments were not continuous on the same plots. Years of early plowing or one-waying alternated with the years in which the specified treatments were used.

This experiment was started to obtain more precise information on tillage treatments and also to obtain additional information not obtainable when a particular treatment is repeated on the same land each year. This information was needed to answer questions of this type: (1) Are treatments that are unproductive when used continuously equally unproductive when they follow good treatments? (2) Are low yields caused by unproductive treatments partially compensated for if the land is prepared by a good method the next year?

There were 23 treatments included in this test each year. Treatments consisted of early, midseason, and late tillage with different tillage implements, combinations of early and midseason tillage, and a few special practices such as burning the stubble and harvesting the crop with a binder.

The experiment was conducted on a block of 48 plots, the east 24 plots of which received the specified cultural practice and the west 24 plots receiving uniform tillage in even-numbered years; the positions were reversed in odd-numbered years. The plots were alternated systematically, each treatment occupying a particular location in each block 8 times. Comparing each treatment with the same plots uniformly treated greatly reduced any error caused by soil variability.

The south 12 plots of each subblock were plowed and the north 12 one-wayed as the tillage practice for the uniform plots. The plowed plots produced an average yield of 1.3 bushels more than the one-wayed plots, a difference that cannot be considered significant in view of the group arrangement of the plots. Furthermore, nearly all the treatments with low yields were in the part plowed in uniform years, so any residual effect from them would be evident on that type of tillage.

TABLE 4.—Average yields of continuous wheat under 23 different cultural practices compared with average yields of uniform plots under 2 tillage practices the same years, Woodward, Okla., 1933-48

Tillage practice before seeding		Average yields <sup>1</sup>		Difference
Variable treatment year	Uniform plot, same year	Variable treatment year	Uniform treatment year	
Early (early July):	Early:	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>
Plowed 8 inches	One-wayed	19.2	18.0	+1.2
Plowed 8 inches, straw burned.	do	19.1	18.0	+1.1
Plowed 8 inches	do	19.7	19.1	+ .6
One-wayed, kept clean with one-way.	Plowed	18.6	18.6	0
One-wayed; plowed 8 inches, August 15.	One-wayed	19.3	19.5	-.2
Plowed 4 inches	Plowed	16.9	17.3	-.4
One-wayed; listed August 15.	One-wayed	17.7	18.5	-.8
Basin-listed	do	17.5	18.3	-.8
Plowed 8 inches, harvested with binder.	do	17.9	18.8	-.9
Disked, kept clean with disk.	Plowed	17.7	18.7	-1.0
Listed, leveled	One-wayed	18.3	19.4	-1.1
Plowed 8 inches, top-dressed in winter.	do	18.9	20.1	-1.2
Plowed 8 inches, planted a month late.	do	15.0	17.1	-2.1
Plowed 4 inches, harvested with binder.	Plowed	18.2	20.4	-2.2
One-wayed, harvested with binder.	do	18.4	21.3	-2.9
Midseason (August 15):				
One-wayed	do	16.4	21.4	-5.0
Plowed 8 inches	One-wayed	12.9	17.9	-5.0
Plowed 4 inches	Plowed	13.8	19.5	-5.7
Listed	One-wayed	11.6	17.7	-6.1
Late (September 15 or later):				
One-wayed	Plowed	10.5	19.5	-9.0
Plowed 4 inches	do	10.1	19.7	-9.6
Disked, straw burned	do	11.1	21.0	-9.9
One-wayed and seeded a month late.	do	<sup>2</sup> 8.0	19.6	-11.6
No cultivation—seed stubbled-in.	do	8.4	21.2	-12.8

<sup>1</sup> L. S. D. from 8-inch early-plowed at 5 percent level = 1.9 bu.

<sup>2</sup> Treatment ended in 1945. Yield adjusted for whole period by comparison with adjoining treatment.

The data from the alternate tillage series are arranged in the order of the differences between the yields of the treated plots and those of the same plots in years of uniform treatment (table 4). A casual inspection shows that time of tillage is extremely important. Where cultivation was commenced early, seeding done at the regular time, and harvesting done in the regular manner, there were no yields that varied more than 1.2 bushels from the yields of the same plots during the uniform years. These differences cannot be considered significant. Early tillage that controls weeds and volunteer growth is effective in promoting good yields, regardless of the particular treatment used. Differences owing to refinements in tillage, such as depth of operation and succession of implements, were small. These refinements were considered very important at the time this experiment was outlined, but it soon became evident that differences of this type were too small to be measured by the methods employed.

Yields resulting from three methods of early tillage were more than 2 bushels to the acre lower than their uniform checks. A reduction as a result of late planting is to be expected. The reduction in yield of the binder-harvested plots approached significance, but all of this reduction cannot be fairly ascribed to the removal of the straw by the binder. There is a loss in grain incident to binding, shocking, curing, hauling, and threshing that exceeds losses incurred in combining.

As mentioned earlier, there was a general fear that the heavy straw left by combining might reduce yields, particularly in years when moisture during the summer was too low for normal decomposition of the straw. The binder-harvested plots were set up to measure any such reduction. Average yields, however, show that there has been a possible gain rather than a reduction when straw was left by combining. Annual yields on combine-harvested land (straw returned) are relatively as good following dry as following wet summers.

Yields from the group of plots first tilled on August 15 were significantly lower—about 5 bushels to the acre—than the early-tilled plots. There was no significant difference between tillage implements or depth of plowing. Annual yields show that in about one-third of the years the yield from tillage starting August 15 was little or no better than that starting a month later (table 27, Appendix).

Tillage commencing September 15 or later caused a further severe reduction in yield of about 4 bushels to the acre below that commencing August 15.

Tillage beginning even later further reduced yields, but for the late one-wayed plot this difference could be ascribed partly to seeding date. Although close direct comparisons cannot be made, yield reductions from late preparation were nearly as severe when practiced alternately as when practiced continuously.

The question of whether well-prepared land benefits by following a treatment producing low yields was not fully answered by this experiment. However, the uniform tillage yields after the late (September 15 or later) treatments had a tendency to be higher following these treatments. The difference was not statistically significant. Any gain in yield from a good tillage practice following an unproductive one was too small to compensate for the loss incurred by use of the unproductive practices.

The differences in yields in this group of plots were probably the most significant of the entire series of experiments. They emphasize the value of early tillage and the striking reduction in yield from late tillage practices. In addition, they show the small differences in yield caused by initial tillage methods. They also indicate, in determining the implement to use, that other factors, such as relative costs of preparation or the surface condition of the soil as the result of a tillage practice, may be more important than any probable difference in yield.

#### FREQUENCY OF PLOWING

An experiment initiated in field B in 1933 was designed to determine whether frequent plowing is necessary or if it can be replaced for one or more years by a shallower and cheaper operation without loss in yield. The shallower operation used the first few years was disking, but this was soon changed to shallow one-waying, because one-waying was more effective in killing weeds and the one-way had come into common use in the area.

There was no decrease in yield from repeated one-waying (table 5). Because the experiment was located on land with a slight fertility gradient from one end of the field to the other, comparisons between rotations are not valid. Comparisons between plots within rotations are relatively accurate, because the yields were obtained on the same plots. The average yield of all plots on plowed land was 19.3 bushels, and that of all plots on one-wayed land was 19.4 bushels; this emphasizes the lack of difference caused by the tillage method.

TABLE 5.—Average yields of wheat on land plowed at stated intervals and disked or one-wayed in the years it was not plowed, field B, Woodward, Okla., 1933-48

Frequency of plowing	Acre yields <sup>1</sup> on—				
	Plowed land	One-wayed or disked land			
		First year	Second year	Third year	Fourth year
	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>
Every year.....	<sup>2</sup> 19. 2	-----	-----	-----	-----
Every other year.....	18. 7	17. 5	-----	-----	-----
Once in 3 years.....	19. 6	19. 7	20. 8	-----	-----
Once in 4 years.....	18. 8	19. 0	18. 9	18. 8	-----
Once in 5 years.....	20. 2	19. 1	20. 1	20. 6	19. 7

<sup>1</sup> L. S. D. at 5-percent level from land plowed every year=1.6 bu.

<sup>2</sup> Average of two plowed plots located at the extreme ends of the block.

#### FREQUENCY OF CULTIVATION

This experiment (field B) was undertaken to determine how often it is necessary to cultivate between early tillage and seeding to obtain weed control sufficient to prevent serious reduction in yield. All plots

in the test were one-wayed as soon as possible after harvest and were given uniform cultivation just before seeding. Cultivations between these dates were designed to give conditions that would represent complete, good, moderate, and poor weed control (table 28, Appendix). Yields of wheat on land one-wayed early and cultivated at different frequencies between harvest and seeding at Woodward, Okla., 1942-48, were as follows:

Frequency of cultivation:	Average yield <sup>1</sup> per acre Bushels
Two-week intervals-----	18.6
Monthly intervals-----	20.2
Once, about mid-August-----	18.3
None between one-waying and preparation for seeding-----	16.4

<sup>1</sup> L. S. D. at 5-percent level=1.9 bu.

The most outstanding result of the experiment was that early-cultivated land, even though untilled between early one-waying and the cultivation at seeding, was much more productive than land where the initial preparation was delayed until near seeding time. The spread in yields between the monthly interval cultivation and no cultivation after initial preparation was far smaller than the spread between early and late initial tillage preparation in the continuous and the alternate tests previously discussed (tables 4 and 5).

Cultivating at monthly intervals was adequate to prevent yield reduction caused by loss of moisture through use by weeds. Yield reductions through cultivations less frequent than at monthly intervals were smaller than anticipated. In a few of the years cultivations at longer intervals were substantially as productive as those performed monthly (table 28, Appendix). The data clearly indicate that complete elimination of weeds at frequent intervals is unnecessary, but the weeds must be killed before they reach a stage of growth when they consume moisture rapidly.

### SPECIAL IMPLEMENTS FOR PREPARING LAND

These experiments cover chiefly methods of tillage that were adopted after the original experiments were outlined. They were introduced into experiments in field B, generally by discontinuing other treatments that closely paralleled treatments that were retained.

### BASIN LISTER

The basin lister was so widely acclaimed when it was first introduced that it seemed desirable to test it, not only as a method of producing wheat annually but also as a method of maintaining fallow land. It, therefore, was included in a number of comparisons. The plots were divided into groups because they were in different parts of the field. Most of the basin-listed plots were tilled by some other method from 1933 to 1936 or 1937. Yields from the previous years are included, and the results show not only the relationship between basin listing and comparable methods but also whether the comparative yields of the plots had been changed by the change in method (table 6).

Group 1 was composed of 3-year rotations of fallow, wheat, wheat. The basin lister and comparable implements were used in cultivating the land being fallowed. Differences between methods were small. The ordinary listing that produced the highest yield during the years of the comparison was also the highest in the years before these treatments were started (table 6). Yields of wheat the second year after fallow are not given, but the yields indicated that there was no carry-over of moisture on basin-listed plots.

Group 2 was made up of alternate wheat and fallow rotations set up as a direct comparison in a part of the field widely separated from group 1. The average differences for the 11-year period that these rotations were in operation was only 0.7 bushel in favor of ordinary listing, a difference too small to be significant.

TABLE 6.—Average yields of wheat obtained per acre by using basin lister compared with yields from other tillage methods, 1937-48, and average yields of wheat for previous cultural practices on same plots

ON FALLOWED LAND

Yields when basin lister was used		Yields when basin lister was not used	
Group, cultural practice and years	Average yield	Cultural practice and years	Average yield
Group 1 <sup>1</sup> (1937-48):	<i>Bushels</i>	Group 1 <sup>2</sup> (1933-36):	<i>Bushels</i>
Plowed early .....	28. 4	Plowed early .....	15. 0
Basin-listed early .....	27. 0	Listed spring .....	15. 7
Basin-listed early .....	28. 0	Listed early .....	15. 1
Listed early .....	29. 1	Listed late .....	17. 4
Group 2 (1938-48):		Not in regular treatments.	
Plowed early .....	26. 0		
Basin-listed early .....	25. 3		

ON CONTINUOUS WHEAT

Group 3 (1938-48):		Group 3 (1933-37):	
Listed early .....	20. 0	Listed early .....	10. 1
Basin-listed early .....	20. 0	Listed early, split ridges .....	10. 5
Group 4 (1938-48):		Group 4 (1938-48):	
Treatment year—		Alternate year—	
Basin-listed early .....	19. 7	One-wayed early .....	20. 6
Listed early .....	21. 0	One-wayed early .....	22. 3

<sup>1</sup> L. S. D. for group 1 at 5-percent level=1.3 bu.

<sup>2</sup> L. S. D. for group 1 at 5-percent level=2.3 bu.

Group 3 compared listing and basin listing in two plots continuously cropped.

Group 4 probably afforded the most accurate comparison in that the comparison is supplemented by yields from the same group of plots during the same period of years when they were cropped uniformly. The difference between listing and basin listing was evidently caused by location rather than by treatment.

The results from the experiments listed above indicate that yields from basin listing are not measurably different from those from ordinary listing. The mechanical action in making the basins pulverizes the soil between basins so that water penetration is slower than with ordinary listings. Basins left by a basin lister sometimes hold water that is lost by runoff from ordinary listing. On the other hand, water may stand for awhile in basins where there has been no runoff on ordinary listing. Any increase in moisture through prevention of runoff by basin listing appears to be offset by greater loss through evaporation.

Unless done on fairly level land or on the contour, basin listing may sometimes be responsible for accelerated erosion. The breaking of one dam usually results in the breaking of other dams in the same furrows farther down the slope with consequent concentration of water.

#### BASIN TILLER

The basin tiller is a pit-forming implement of comparatively light draft and is pulled behind a one-way or other tillage implement. It was believed by many that the pits would hold water and prevent loss by runoff and thus increase wheat yields. The basin tiller was used for a period of 10 years on a plot continuously cropped to wheat. Yields from this plot were compared with those from an adjacent plot cultivated with the same implements at the same time but not basin-tilled. The average yields of the two methods were 13.9 and 13.1 bushels to the acre, respectively. The greatest difference between the two in any single year was only 3 bushels to the acre. The basin-tiller method sometimes prevents runoff during comparatively light rains, and owing to the staggered location of the pits and the roughness of the surface left by the pitting operation, runoff water is not concentrated when runoff does occur. However, not enough additional water is retained by the pitting operation to affect wheat yields materially.

#### SUBSURFACE CULTIVATOR

Cultivation with an implement that leaves all or nearly all the stubble on the surface was introduced into the continuous-cropping plots at two field locations. It was also introduced into a 3-year fallow rotation, not as a method of preparing fallowed land but to test its use on land where combined wheat on fallowed land had left a comparatively heavy straw and stubble cover. The Noble cultivator with a straight blade was used in the early years and one with wide sweeps in later years.

Yields on fallowed wheat stubble were more variable for the period from 1943 to 1948 than for the earlier period when the land was uniformly one-wayed (table 7). The subsurfaced and the two plowed plots showed about the same difference in yield for the two periods.

The first pair of continuously cropped plots showed a considerably lower yield for the plot subsurfaced by the Noble blade. The second pair produced yields that were substantially equal.

The greatest benefit from sub tillage lies in its value for erosion control and not in its immediate effect on yields. These results

indicate that subtilling did not increase yields, but that on the average it reduced them little. Loose, undecomposed straw on the surface makes seeding with an ordinary drill difficult unless the soil is packed before seeding.

TABLE 7.—*Average yields of wheat on plots cultivated by subsurface tillage compared with yields from other plots using other tillage methods, field B, Woodward, Okla., 1933-48*

ON FALLOWED WHEAT STUBBLE

Acre yields when subsurface tillage was used		Acre yields on same plots when subsurface tillage was not used	
Cultural practice and year	Average yield	Cultural practice and year	Average yield
1943-48: <sup>1</sup>	<i>Bushels</i>	1933-42: <sup>2</sup>	<i>Bushels</i>
Early Noble-bladed.....	22.6	Early one-wayed.....	18.5
Early one-wayed.....	20.3	Do.....	18.8
Do.....	24.1	Do.....	18.1
Early plowed, 8 inches.....	22.4	Do.....	17.8
Early plowed, 4 inches....	21.9	Do.....	17.5

ON CONTINUOUS WHEAT

1941-48:		1933-40:	
Early Noble-bladed.....	21.6	Early duckfooted or chiseled.	12.7
Early plowed, 8 inches....	25.1	Early plowed, 8 inches..	13.1
Early Noble-bladed.....	16.0		
Early one-wayed.....	16.4		

<sup>1</sup> L. S. D. at 5-percent level=1.3 bu.

<sup>2</sup> L. S. D. at 5-percent level=1.1 bu.

EFFECT OF SEEDING VARIABLES ON WHEAT YIELDS

When these experiments were started there were many opinions regarding the value of various types of drills, both for regular and for delayed seeding of wheat. Experiments were outlined to obtain authentic information. Three types of drills on four types of land preparation were used. The drills were (1) the Dempster deep-furrow shovel-type drill with 14-inch row spacing; (2) the Superior deep-furrow disk drill with 14-inch spacing; and (3) the Superior regular-furrow disk drill with 7-inch spacing.

Seedings were made at the time the other plots in the field were sown and about a month later. Seeding dates for the regular sowing ranged from September 20 to November 9, and the average seeding date was October 9. The late seedings ranged from October 22 to December 23, with the average November 7.

Comparisons did not include all possibilities (table 8). Emphasis was placed on furrow drills for late seeding, because it was assumed

that wheat sown too late to form an adequate cover must be protected by a ridged surface such as that left by a furrow drill.

Comparisons within each of the four tillage groups are valid, but those between treatments in different tillage groups are not.

Seeding at the regular date was better than seeding a month late on all methods of seedbed preparation. The reduction in yield from late seedings on fallowed or early-prepared land was greater for the Dempster than for the other types of drills.

Average yields for the deep-furrow drills were about equal and no higher than yields obtained with the 7-inch drill.

TABLE 8.—Average yields of wheat sown with 3 types of drills at 2 dates on seedbeds prepared by 4 methods, Woodward, Okla., 1933-40

Seedbed preparation and time of seeding	Average acre yields with—		
	Dempster deep-furrow shovel-type drill	Superior deep-furrow disk drill	Superior 7-inch disk drill
Fallow:			
Seeded—	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>
Regular time .....	18. 6	18. 9	20. 3
Month late .....	15. 6	17. 3	18. 5
Plowed early:			
Seeded—			
Regular time .....	11. 8	11. 8	13. 0
Month late .....	11. 2	11. 1	-----
One-wayed early:			
Seeded—			
Regular time .....	15. 0	13. 3	12. 2
Month late .....	11. 9	12. 9	11. 1
No preparation:			
Seeded—			
Regular time .....	4. 6	5. 6	5. 8
Month late .....	3. 3	3. 0	-----

It had been thought that on land given no preparation before seeding the Dempster drill might give better results than other drills because the wide shoe gave an action similar to plowing or listing. In practice, both disk drills gave higher yields than the Dempster for the regular date of seeding on land not cultivated. In the month-late plowing, the Dempster furrow drill was slightly better than the Superior disk drill. All yields on land given no preparation were very poor. This experiment was ended in 1940, as the land had become so foul with grassy-type weeds that continuation was neither practicable nor desirable.

Results with types of drills show that major differences in production have not resulted from the type of drill used. They also show that, contrary to general opinion, the deep-furrow drill was not more productive when seeding was done late.

## ROTATIONS WITH SUMMER FALLOW

The use of summer fallow in the cropping system of the area has been thoroughly investigated. Studies included comparisons of alternate-cropped and fallowed land with annually cropped land; methods of fallow to determine if the efficiency of fallow can be improved through the length of the fallow period or through the implement used in fallow maintenance; frequency of fallow to determine if there is a carry-over of moisture from fallow beyond the crop immediately following; and the use of manure and other organic amendments in fallow systems.

## COMPARISON OF ALTERNATE FALLOW WITH CONTINUOUS CROPPING

The chief value of summer fallow in most areas is insurance against failures. Even though the acre yield on fallowed land is not double that on land where a crop is grown every year, it may have a value if it prevents failures. Unless the yield is nearly double that of land continuously cropped by good methods or provides insurance against failure, it is not regularly adapted to a strictly grain-farming system. It may have a place in a cropping system involving other crops, as will be discussed later.

The best direct comparison of fallow with continuous cropping was in field A. In this field, the 34-year average wheat yield on land fallowed in alternate years was 22.2 bushels to the acre. This was



FIGURE 5.—A part of field B, viewed from the north side. Fallowed series of plots are at the left. These are in the 3-year rotations of fallow, wheat, wheat.

only 28 percent higher than the average yield of 17.3 bushels to the acre on two adjacent early-prepared plots cropped continuously. Probably the best comparison in field B was between yields on fallowed land and yields on early one-wayed land in a series of rotations (fig. 5 and table 29, Appendix). In this group the average yield of wheat on fallow was 25.2 bushels to the acre. This was an increase of only 33 percent over the average yield of 18.9 bushels that was obtained on early-prepared land the second year after fallow. On

the basis of yields, alternate fallowing and cropping is not recommended for this region.

TABLE 9.—*Percentage of wheat yields falling within specified yield categories on fallowed land and on continuously cropped land, fields A and B, Woodward, Okla., 1915-48*

Yield category (bushels per acre)	Percentage of yields in different categories			
	Field A (1915-48)		Field B (1933-48)	
	On fallowed land	On cropped land	On fallowed land	On cropped land
	Percent	Percent	Percent	Percent
0 to 5.0.....	3	3	0	0
5.1 to 10.0.....	12	12	0	13
10.1 to 20.0.....	35	58	31	56
20.1 to 30.0.....	29	24	44	19
30.1 to 40.0.....	21	3	12	12
More than 40.0.....	0	0	13	0

Fallow has been ineffective in preventing wheat failures (table 9). In field A, the percentage of yields in the 0- to 5- and 5- to 10-bushel categories was the same on fallowed as on cropped land. The chief function of fallow was to increase yields in fair and good years. Fifty percent of the yields on fallowed land were more than 20 bushels to the acre. Yields of more than 30 bushels to the acre on fallowed land exceeded those on annually cropped land by the ratio of 7 to 1.

During the 16 years that experiments were in progress in field B, there was no yield of less than 10 bushels to the acre on fallowed land and only 2 yields of less than 10 bushels on annually cropped land. Moreover, the chief function of fallow appears to be the production of higher yields in fair or good years instead of the prevention of failures. Approximately two-thirds of the yields on fallow land were more than 20 bushels to the acre as compared with about one-third on cropped land. Several yields of more than 40 bushels to the acre were produced on fallowed land and none on cropped land.

Despite the greater number of higher yields on fallowed land, alternate wheat and fallow is not recommended under cropping conditions like those at Woodward. On the average, in both fields, alternate fallow and cropped land produced only two-thirds as much wheat per acre as land continuously cropped by good methods. This severe reduction in yield was not compensated for by material reduction in the number of very low yields or failures. The use of fallow also resulted in a more rapid loss of organic matter and nitrogen.

#### FREQUENCY OF FALLOW

A series of rotations with 1 to 4 years of wheat between years of fallow was started to determine if there is a carry-over of moisture

on land that has been fallowed that extends beyond the crop immediately following.

The yield of wheat in the rotation cropped and fallowed in alternate years was significantly higher than those of rotations with more than 1 year of wheat between fallow periods (table 10). The possibility of a carry-over of moisture was not supported by the yields for the second and third year after fallow. For some unexplained reason, the yield of the land 4 years after fallow was significantly lower than that of land 2 or 3 years after fallow in the same rotation.

Since the yield on fallowed land was much less than double the yield of wheat after wheat (table 10), it was to be expected that the less frequently fallow was used in the system, the higher the acre yield of the rotations as a whole would be. The results from these rotations show that the carry-over of moisture from fallowed land at Woodward is not significant.

TABLE 10.—*Yields of wheat on land fallowed at different intervals, Woodward, Okla., 1933-48*

Rotation	Average yields per acre <sup>1</sup>				Average yield per acre in rotation
	1st year after fallow	2d year after fallow	3d year after fallow	4th year after fallow	
	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>
Fallow, wheat-----	24.1	-----	-----	-----	12.1
Fallow, wheat, wheat-----	22.6	17.6	-----	-----	13.4
Fallow, wheat, wheat, wheat-----	22.4	17.5	16.8	-----	14.2
Fallow, wheat, wheat, wheat, wheat-----	22.2	18.1	18.2	16.2	14.9

<sup>1</sup> L. S. D. at 5-percent level between yields on fallowed land=1.3 bu.; L. S. D. between yields on cropped land=1.5 bu.

## ROTATIONS WITH OTHER CROPS

### WHEAT FOLLOWING CULTIVATED CROPS

The effect of the different crops grown in cultivated rows on yields of wheat the following year has been studied in a group of 2-year rotations, located in both fields (table 11).

Yields of wheat following corn and cowpeas were about equal and approximately equivalent to the yield of wheat grown continuously on early-prepared land (table 11).

Yields on both milo and kafir land were so low that—except in an emergency—seeding wheat after either of these crops is undesirable.

The average yield of wheat following milo was slightly higher than after kafir in field B, while the reverse was true in field A. However, during the period 1933-48, the years that the field B experiments were in progress, the yield following milo was also higher in field A. The change in relative yields of the two sequences in field A may be a result of the change in harvesting methods for milo. Beginning in

1932, milo stover was left standing. Wheat seeded in sorghums was damaged somewhat when the stover was harvested. It may be that the absence of such damage after milo stalks were allowed to stand accounted for the change in its yield relative to that following kafir. The milo stalks in field B were not harvested during the progress of the experiment.

TABLE 11.—*Yields of wheat following different row crops and on early-prepared continuously cropped land, fields A and B, Woodward, Okla., 1919-48*

Preceding crop	Average acre yield <sup>1</sup> of wheat	
	Field A, 1919-48	Field B, 1933-48
	<i>Bushels</i>	<i>Bushels</i>
Corn.....	18. 4	19. 3
Cowpeas.....	18. 4	19. 8
Milo.....	12. 5	13. 3
Kafir.....	13. 1	12. 8
Cotton.....		15. 0
Wheat, continuous.....	20. 8	19. 4

<sup>1</sup> L. S. D. from wheat grown continuously, at the 5-percent level=2.7 bu. for field A; 2.5 bu. for field B.

The long-time effect of the different crops on wheat yields was studied through 5-year moving averages. The yield of wheat after cowpeas, which were harvested for hay, compared with yields following sorghums was relatively better in the later years of the experiment than in earlier periods. This was consistent in both fields. Wheat yields on cowpea land increased in comparison with those on cornland in field A, but to a lesser extent than that following sorghums. No such trend was apparent for the shorter period in field B. Results indicate that cowpeas harvested for hay were less soil depleting than sorghums and perhaps slightly less so than corn.

Average yields of corn and cowpeas were low, and cowpea hay is so difficult to handle that the acreage of these crops is very limited in this area. Cowpeas leave the soil without protection against blowing; therefore, planting them in large fields is not generally recommended.

#### WHEAT FOLLOWING MILO IN WIDE-SPACED ROWS

During the early 1930's there was a widespread opinion that sorghum in wide-spaced rows was comparable with fallowed land as a preparation for wheat. The occasional rows of sorghum were expected to provide some grain and the standing stalks to provide wind-erosion control. Experiments using rotations with two types of sorghum in 16.5-foot rows followed by wheat were set up to obtain information regarding this matter.

There was also a belief that early-maturing dwarf sorghums could be planted after wheat harvest and would produce some grain without injury to a crop of wheat sown that fall. To test the validity of this belief, dwarf sorghums in 16.5-foot rows were planted as soon after wheat harvest as the land could be prepared. In this sequence both a wheat crop and a sorghum crop were harvested from the same land each year.

Yields of wheat and sorghum in alternate years are compared with wheat grown on fallowed land (table 12), whereas wheat and sorghum grown in the same year are compared with continuous wheat.

TABLE 12.—*Yields of wheat following milo in 16.5-foot rows as compared with wheat grown continuously or alternately with fallow at Woodward, Okla., 1935-48*

Crop sequences	Average acre yield <sup>1</sup>	
	Wheat	Milo
	<i>Bushels</i>	<i>Bushels</i>
Wheat and dwarf yellow milo, alternate years .....	14. 0	10. 5
Wheat and combine milo, alternate years .....	17. 3	6. 8
Wheat and fallow, alternate years .....	<sup>2</sup> 25. 9	-----
Wheat and combine milo, the same year .....	18. 1	3. 8
Wheat and Sooner Milo, the same year .....	17. 1	3. 2
Continuous wheat .....	20. 6	-----

<sup>1</sup> L. S. D. for comparing wheat yields with continuous wheat at 5-percent level = 2.9 bu.

<sup>2</sup> Average of a group of fallowed plots.

It soon became evident that land with milo in 16.5-foot rows did not approach fallow as a method of preparation for growing wheat. The roots of milo affected the moisture content of the soil and the subsequent growth of wheat fully 6 feet on each side of the row. In many years this was noticeable in the early growth and heading of the wheat. In some years it was observed that only about a 4-foot strip midway between the rows headed at the same time as wheat on fallowed land. The reductions in wheat yields from this practice below those of wheat on fallow were greater than the quantities of milo produced.

Growing milo after wheat harvest was unsuccessful. The reduction in wheat yields below those under continuous cropping were not large, but in most years the milo did not pay for the harvesting. The average yields of between 3 and 4 bushels to the acre are the averages of a few yields of slightly more than 10 bushels to the acre and of many exceedingly low yields or failures.

#### ROTATIONS WITH SWEETCLOVER

Two rotations with sweetclover were started in field B. One of these was sweetclover, wheat, wheat, with the sweetclover fall-seeded

on land tilled soon after the wheat had been removed. The period beginning with 1933 was extremely adverse for fall establishment and summer survival of sweetclover. During the 10 years that this experiment was in progress only one crop of sweetclover was harvested, and the acre yield was less than three-fourths ton. Wheat yields in this rotation do not reflect differences caused by growing sweetclover and are not discussed.

The other rotation was a 5-year one consisting of drill-seeded sorghum, sweetclover, sweetclover, wheat, wheat. In this rotation the sorghum was harvested for hay and the stubble left as a protective cover for the spring-seeded sweetclover. Despite the protective cover left for sweetclover seedlings, only two light yields of second-year sweetclover were obtained. During this period the yield of wheat after sweetclover harvested for hay was approximately the same as that of wheat after wheat.

## ROTATIONS INVOLVING ORGANIC AMENDMENTS

### LEGUME GREEN-MANURE CROPS

Two-year rotations including legume green-manure crops afforded an excellent opportunity to study green-manure crops plowed under in comparison with the same crops harvested for hay in field B. Two of the green-manure crops used, hairy vetch (fig. 6) and Austrian Winter peas, were fall-planted and were plowed under early enough in the spring to store a quantity of water comparable with that on fallowed land. The third green-manure crop, cowpeas, was plowed under much later in the season. The cowpeas were grown in cultivated

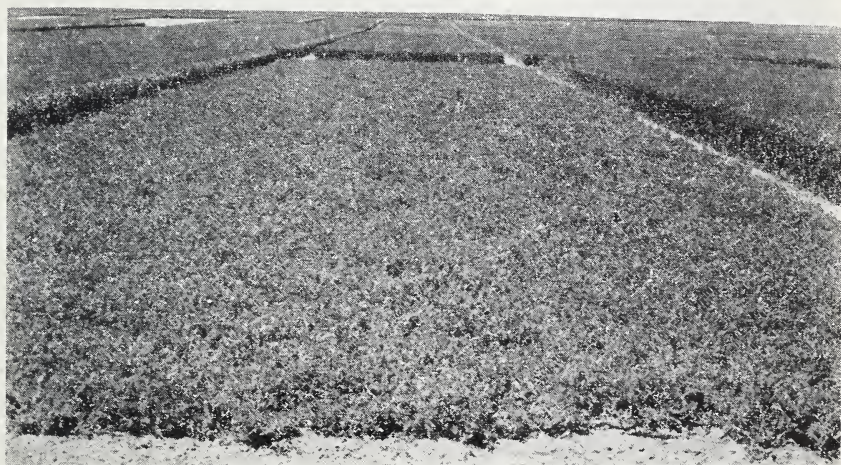


FIGURE 6.—A plot of hairy vetch early in May of a good crop season.

rows. There was often some residue of moisture when they were plowed under.

In this group of rotations, the wheat yield after cowpeas harvested for hay was significantly lower than any other treatment in this group (table 13: table 30, Appendix). The most logical explanation for this is that plots where crops were harvested for hay usually were not cultivated immediately after the hay was removed, and some second growth often resulted. Cowpea hay was usually removed in August, and between that time and wheat seeding time moisture lost was not restored. Vetch and peas, on the other hand, were harvested much earlier in the season, and there was a better chance for rainfall to restore moisture.

TABLE 13.—*Average yields of wheat on land where legume crops have been plowed under and on fallow and yields of wheat and of hay on land where the same legume crops have been harvested for hay, field B, Woodward, Okla., 1933-48*

Crop and cultural practice	Acre yields of—	
	Wheat <sup>1</sup> after legume crop or fallow	Legume hay
Austrian Winter peas:	<i>Bushels</i>	<i>Pounds</i>
Plowed under for green manure.....	24. 7	-----
Harvested for hay.....	26. 1	1, 382
Hairy vetch:		
Plowed under for green manure.....	23. 8	-----
Harvested for hay.....	24. 7	2, 158
Cowpeas:		
Plowed under for green manure.....	24. 1	-----
Harvested for hay.....	19. 4	1, 742
Fallow (average of 8 plots).....	25. 9	-----

<sup>1</sup> L. S. D. from wheat on fallow at 5-percent level=2.9 bu.

Slightly higher yields of wheat were obtained after vetch and Austrian Winter peas harvested for hay than after the same crops plowed under for green manure. The fall growth of wheat on the green-manured land was usually more vigorous, but this vigor was not reflected in the final grain yield. Average yields of 1,382 pounds per acre of pea hay and 2,158 pounds of vetch hay were harvested in addition to about equivalent wheat yields. For the period covered by these experiments, one could not afford to plow under a legume crop.

Data from comparable fallowed land are not available for a close comparison, but the average yields on a number of fallowed rotations indicate that yields from green-manured and fallowed land are about equal. As green manuring is an even more expensive operation than fallowing, it is not recommended—on the basis of wheat yields alone—in the cropping system of the area.

#### GREEN-MANURE CROPS AND MANURED AND UNMANURED FALLOW

A set of 4-year rotations was established in field A to study the comparative effect of manure and of green manure in the production

of wheat and kafir. Only the effect on the wheat is discussed. The rotations were as follows:

Fallow, wheat, fallow, kafir;  
 Fallow, wheat, rye green manure, kafir;  
 Fallow, wheat, cowpeas green manure, kafir;  
 Fallow, wheat, manured fallow, kafir.

In this particular group of rotations the differential treatment preceded the kafir, and the wheat yields represented only the residual effects. Average acre yields of wheat on fallow in 4-year rotations with and without soil amendments, Woodward, Okla., 1915-48, were as follows:

Soil amendment:	Average wheat yields Bushels <sup>1</sup>
None-----	18.5
Rye green manure in the rotation-----	23.1
Cowpea green manure in the rotation-----	22.8
Manure in the rotation-----	26.6

<sup>1</sup> L. S. D. from no soil amendment at 5-percent level=2.5 bu.

The difference between the unmanured and the manured fallow is striking. The soil in the unmanured rotation is somewhat lighter, but the fact that the difference was not primarily due to soil type is shown in the moving averages in figure 7. The spread in yields has increased with the years, particularly in the favorable period of the 1940's.

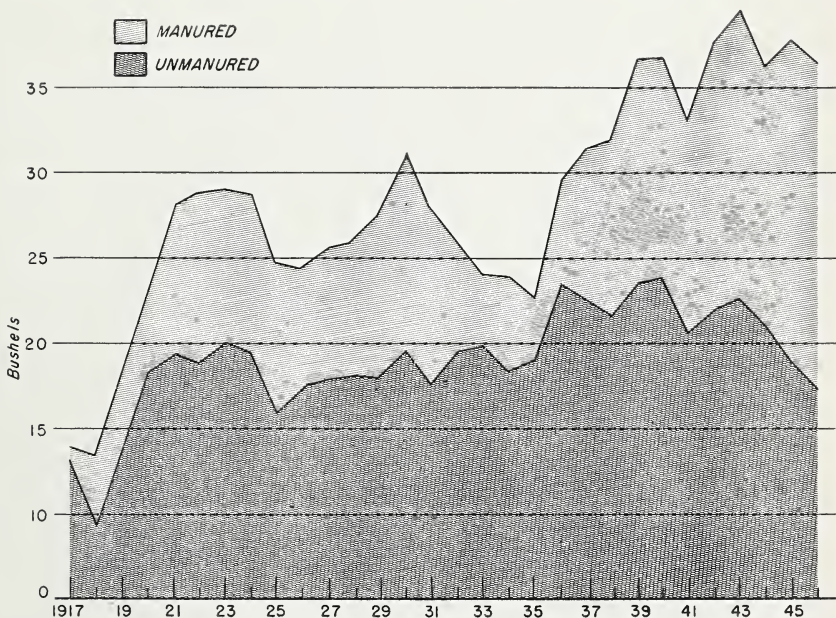


FIGURE 7.—Five-year moving averages of wheat yields in manured and unmanured rotations including fallow, Woodward, Okla., 1915-48.

Similar trends have been shown in comparing the unmanured and the green-manure rotations, but the spread was much smaller.

The differences in yield were not consistent, but varied exceedingly with season. The generalization that the differences in yields between

the manured and unmanured rotations were greatest in years of high production and least in years of low production is generally true, but there were exceptions (table 14). In 1926 and 1942, for example, differences caused by manuring were small, yet production levels were high. On the other hand, there were cases in which the difference was above average in years of below-average production. The potential difference in annual yield was higher toward the end of the experiment than during the early or middle periods. The average difference for the period was 8.1 bushels.

TABLE 14.—*Yields of wheat and differences in yields in manured and unmanured rotations, field A, Woodward, Okla., 1915-48*

Year	Acre yield			Year	Acre yield		
	Manured rotation	No manure in rotation	Difference		Manured rotation	No manure in rotation	Difference
	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>		<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>
1915-----	27. 7	31. 2	-3. 5	1933-----	13. 7	13. 2	. 5
1916-----	3. 3	1. 8	1. 5	1934-----	16. 3	21. 0	-4. 7
1917-----	13. 5	10. 5	3. 0	1935-----	19. 7	20. 5	-. 8
1918-----	8. 3	9. 2	-. 9	1936-----	23. 3	17. 5	5. 8
1919-----	17. 1	12. 5	4. 6	1937-----	26. 0	24. 0	2. 0
1920-----	24. 7	12. 3	12. 4	1938-----	47. 7	33. 7	14. 0
1921-----	30. 7	27. 2	3. 5	1939-----	26. 2	16. 7	9. 5
1922-----	36. 2	30. 3	5. 9	1940-----	22. 7	16. 3	6. 4
1923-----	31. 8	14. 7	17. 1	1941-----	46. 2	26. 8	19. 4
1924-----	20. 5	9. 3	11. 2	1942-----	26. 5	26. 0	. 5
1925-----	26. 0	17. 5	8. 5	1943-----	28. 8	16. 5	12. 3
1926-----	28. 8	25. 5	3. 3	1944-----	49. 8	24. 2	25. 6
1927-----	15. 2	12. 7	2. 5	1945-----	32. 0	19. 7	12. 3
1928-----	30. 8	22. 6	8. 8	1946-----	29. 3	18. 2	11. 1
1929-----	26. 0	11. 7	14. 3	1947-----	34. 2	14. 3	19. 9
1930-----	28. 5	18. 7	9. 8	1948-----	22. 2	10. 2	12. 0
1931-----	38. 2	24. 8	13. 4				
1932-----	32. 2	19. 7	12. 5	Average	26. 6	18. 5	8. 1

#### MANURE AND STUBBLE BURNING

Manure was used in two 3-year rotations of fallow, wheat, wheat in field B. In one rotation, manure was applied to the land being fallowed. In the other, manure was applied as a winter top dressing to the wheat on fallowed land. Neither of these rotations differed significantly from similar rotations not receiving manure during the 16 years that the experiment was in progress. This held true for both the crop on fallowed land and the second crop after fallow.

On one rotation, the stubble from the wheat on fallowed land was burned. Yields on this rotation were almost identical with those on the manured rotation, both for the crop on fallowed land and for the second crop. The plot not burned, however, maintained enough residue on the surface to resist wind erosion (fig. 8).

On the more fertile soil in field B, a 16-year period did not appear long enough to bring about measurable changes, either through the



FIGURE 8.—Differences in crop residues on one-wayed plots at seeding time: Left, straw burned at harvest; right, not burned.

application of manure every third year or through the destruction of stubble at similar intervals. A similar lack of response to manure and to burning stubble on land continuously cropped to wheat was shown by data given in table 3.

#### EFFECT OF NITROGEN AND PHOSPHORUS ON WHEAT YIELDS

A fertilizer experiment was conducted during the period 1933–39 on an area of Pratt loamy fine sand (field A) that had suffered more sheet erosion than the rest of the field and was in a relatively low state of fertility. The experiment included 3 replications of each of 12 treatments. In addition, all treatments were bordered on each side by unfertilized plots that gave additional precision in evaluating the effect of the various fertilizers. Individual plot yields were not taken in 1933. The experiment was on land cropped each year to wheat and prepared by good cultural methods. Triple superphosphate (45 percent  $P_2O_5$ ) was applied in the row in the fall, muriate of potash was applied as a broadcast application in the fall, and sodium nitrate was broadcast either as a fall or spring application. Manure was applied as a top dressing in the spring. The results were positive and clearcut (table 15). Increases in yields averaging 3.6 bushels per acre or more were obtained when both phosphorus and nitrogen were applied.

Both nitrogen and phosphorus when applied alone produced increases in yield, but the increases were generally less than half as great as where both were applied. Potassium and manure when applied alone did not increase yields significantly.

In 1 year (1938) in the 6 covered by these data the better treatments increased yields by about 10 bushels to the acre, in 2 years (1936, 1939) the margin was 5 to 10 bushels, in 2 (1934, 1935) the increase was less than 5 bushels, and in 1 (1937) the application of fertilizer resulted in a reduction in yield.

The largest average increase from any fertilizer treatment, 4.5 bushels to the acre, was unprofitable at the prices for fertilizer and wheat prevailing during the 1934–39 period.

TABLE 15.—*Wheat yields on fertilized plots and on adjacent check plots<sup>1</sup> of Pratt loamy fine sand (field A), and precipitation for crop years, Woodward, Okla., 1934-39*

Fertilizer treatment <sup>2</sup> and precipitation	Per acre yields <sup>3</sup>						Increase over check	
	1934	1935	1936	1937	1938	1939	Average	Percent
	Bushels	Bushels	Bushels	Bushels	Bushels	Bushels	Bushels	
8 lb. N in fall and in spring; 67.5 lb. P	23.5	19.5	14.1	5.3	22.8	17.9	17.2	4.5
Adjacent checks	19.7	17.2	7.8	8.8	12.3	10.1	12.7	35
8 lb. N in fall and 16 lb. in spring; 67.5 lb. P	23.5	18.5	14.6	7.6	22.5	16.8	17.3	4.4
Adjacent checks	19.8	18.0	9.0	9.2	11.0	10.5	12.9	34
8 lb. N in fall; 67.5 lb. P	23.8	17.1	13.2	9.0	18.6	17.1	16.5	3.6
Adjacent checks	19.9	16.6	8.1	10.4	11.1	11.0	12.9	28
8 lb. N in fall and 16 lb. in spring	21.5	18.1	9.1	9.0	19.4	12.4	14.9	2.7
Adjacent checks	20.2	16.7	6.7	10.4	9.3	10.1	12.2	22
67.5 lb. P; 25 lb. K	22.3	17.7	5.8	10.6	11.3	14.3	13.7	2.0
Adjacent checks	18.4	16.4	5.3	12.2	8.4	9.5	11.7	17
24 lb. N in fall	20.9	19.7	10.0	6.5	21.3	13.0	15.2	2.1
Adjacent checks	20.6	19.2	10.1	9.8	9.5	9.6	13.1	16
67.5 lb. P	22.1	16.4	8.4	10.4	13.2	11.8	13.7	1.4
Adjacent checks	18.6	18.1	7.3	10.1	10.6	8.8	12.3	11
24 lb. N in spring	19.5	15.5	8.2	11.0	14.6	12.0	13.5	1.3
Adjacent checks	18.7	16.0	7.0	12.0	9.1	10.4	12.2	8
25 lb. K	18.9	16.0	6.9	12.0	11.5	10.8	12.7	.9
Adjacent checks	18.1	16.4	5.8	10.9	9.6	9.9	11.8	6
8 lb. N in spring	19.5	17.6	7.2	11.2	11.9	10.4	13.0	.7
Adjacent checks	18.9	18.7	6.9	11.2	8.5	9.3	12.3	2
Top-dressed with manure in spring	19.9	15.8	7.0	10.1	12.4	10.3	12.6	.3
Adjacent checks	19.4	16.8	7.0	10.2	10.1	10.1	12.3	3
No fertilizer	19.3	18.1	7.2	10.0	14.8	9.3	13.1	.4
Adjacent checks	19.7	18.2	8.2	11.2	11.0	8.1	12.7	
Crop year precipitation—inches	17.42	22.91	15.74	14.90	29.66	23.58	20.70	

<sup>1</sup> Check yields are averages of 6 plots (2 check plots adjoining each of the triplicated treatment plots.) Fertilized plot yields are averages of 3 plots.

<sup>2</sup> N=nitrogen, applied as sodium nitrate ( $\text{NaNO}_3$ ); P=phosphorus, applied as triple superphosphate (45 percent  $\text{P}_2\text{O}_5$ ); and K=potassium, applied as muriate of potash (KCl). Phosphorus and potassium were always applied in the fall.

<sup>3</sup> L, S, D, to test a treatment mean against its check mean at 5-percent level=0.7; at 1-percent level, 1.00. L, S, D, to test 2 treatment means or 2 check means at 5-percent level=1.9; at 1-percent level, 2.50. L, S, D, to test the differences between a treatment mean and its check mean with the differences between other treatment means and their respective check means at 5-percent level=1.0; 1-percent level, 1.4.

The precipitation for the period covered by these experiments was somewhat below average, but this period covered a fairly representative range of variations for Woodward (table 22, Appendix). Therefore, continued testing of these fertilizer treatments over a longer period should not change these relationships materially. However, costs of fertilizer and prices of wheat are subject to change, which could make the fertilization of wheat on this soil a profitable practice.

The protein content of the wheat was determined in 3 of the years. It was found that nitrogen applications increased the protein content of wheat almost directly proportional to the quantity of nitrogen applied. The extremes were 14.9 percent protein with 24 pounds of nitrogen and 13.2 percent without nitrogen. This increase would be of little value except in years when a premium is paid for high-protein wheat.

In 1941 an experiment was begun in field B to determine if there was a response to either nitrogen or phosphorus on a soil more fertile than the Pratt loamy fine sandy soil of field A. The experiment was conducted both on continuously cropped and on fallowed land. The purpose of the test on fallowed land was to find out if a higher level of fertility would permit wheat on fallowed land to make more efficient use of its favorable water supply. There was no replication except of check plots; the intention being to determine first whether there was a response to fertilizer or not and then to conduct a critical experiment if results seemed to warrant it.

Results from the first 6 years of the experiment (1941-46) showed only moderate response of the wheat to fertilizer (table 16). The most favorable yield increase, averaging 2.4 bushels per acre, was obtained with the addition of both nitrogen and phosphorus to continuously cropped land. There was only 1 year (1944) of the 6 when the fertilizer treatments as a whole would have been profitable. By contrast, large increases from fertilizers were realized in the 1947 season. Increases of approximately 20 bushels to the acre were obtained on fallowed land from nitrogen alone or in combination with phosphorus and on cropped land when both nitrogen and phosphorus were applied. Fertilization of wheat in 1947 was highly profitable. A similar response, but to a lesser degree, was realized in the 1949 season.

On continuously cropped land wheat receiving both nitrogen and phosphorus produced a 9-year average increase of 7.2 bushels to the acre. This is a profitable increase. However, about 70 percent of this increase was in the two years 1947 and 1949. Nitrogen applied at the same rate and time but without phosphorus produced an average increase in yield of only 0.9 bushel per acre. On fallowed land the yield increase from nitrogen without phosphorus was higher than that for the combination of the two plant nutrients. The practice of alternately fallowing and cropping land to wheat has not been profitable at Woodward, and there is no indication that the application of fertilizer will alter this relationship appreciably.

Yields of both fertilized and unfertilized wheat were influenced by the quantity of precipitation and its distribution. Both of the years when high response to fertilizer was obtained had above-average fall precipitation, adequate but not excessive winter precipitation, high rainfall during the fruiting period, and more-than-average May rainfall.

TABLE 16.—*Increases in wheat yields from fertilized plots over adjacent checks and a comparison between responses on continuously cropped and on fallowed land (field B), Woodward, Okla., 1941-49*

Year	Yield increases per acre over adjacent checks on—			
	Continuously cropped land, using—		Fallowed land, using—	
	Nitrogen <sup>1</sup> and phosphorus <sup>2</sup>	Nitrogen <sup>1</sup>	Nitrogen <sup>1</sup> and phosphorus <sup>2</sup>	Nitrogen <sup>1</sup>
	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>
1941-----	3.6	-2.7	1.0	0
1942-----	-2.5	.2	-2.7	-4.0
1943-----	1.6	-1.4	-1.0	4.0
1944-----	3.5	1.5	6.3	8.0
1945-----	3.6	-.3	2.3	6.0
1946-----	4.5	1.5	-6.3	-2.0
1947-----	22.9	7.9	19.4	22.0
1948-----	5.3	-1.4	2.0	5.3
1949-----	22.2	2.8	13.0	5.3
6-year average increase, 1941-46-----	2.4	-.2	-.1	2.0
9-year average increase, 1941-49-----	7.2	.9	3.8	5.0
Average yield for treatment 1941-49--	27.6	21.5	27.7	28.9

<sup>1</sup> Nitrogen was applied at the rate of 10 pounds to the acre in the fall and 20 pounds in the spring.

<sup>2</sup> Phosphorus was applied at the rate of 67½ pounds of P<sub>2</sub>O<sub>5</sub> to the acre in the fall.

Two treatments involving high rates of nitrogen application in the fall and spring were begun in 1944 and 1945. The high rate of nitrogen (100 pounds per acre) produced yields greater than those from 30 pounds of nitrogen alone, but far lower than that obtained from 30 pounds of nitrogen in combination with phosphorus. The best average increase for the high rate of nitrogen was from the fall application.

Results from this experiment indicate that increases from the nitrogen-phosphorus treatment may be high enough to be profitable. This profitable average increase, however, has resulted from large increases in a few years, rather than from regular moderate increases.

#### RELATIONSHIP OF WHEAT YIELDS TO CLIMATIC FACTORS

In dry-land areas most of the annual variations in yields are known to be caused by weather and have generally been ascribed to the amount of precipitation. At this station measurement of precipitation adjacent to the experimental field gives an unusual opportunity of determining the effect both of annual precipitation and that for shorter periods on the yields of wheat. Since a wheat crop at Wood-

ward approaches maturity about June 1, the following relationships are based on crop-year precipitation, that is, June 1 of one year to May 31 of the following year.

At Woodward the crop-year precipitation has ranged from 14.40 inches in 1948 to 36.05 inches in 1924. The average is 23.76 inches. The correlation coefficient between crop-year precipitation and yields of wheat is 0.491 (table 17). This value is significant at the 5-percent level, but not nearly so high as might be expected. That high annual precipitation is necessary for favorable wheat yields is brought out by the fact that in only 3 years have above-average yields been produced with below-average rainfall; and in 2 of these years the precipitation was only slightly below average. Evidently a quantity of precipitation that approaches average is needed to produce average wheat yields, but there are other factors that limit the effectiveness of total rainfall.

TABLE 17.—*Correlation coefficients of crop-year rainfall and yields of winter wheat, Woodward, Okla., 1915-48*

Month or period	Correlation coefficient <sup>1</sup>	Month or period	Correlation coefficient <sup>1</sup>
June-----	-0. 296	February-----	0. 343
July-----	. 211	March-----	. 402
August-----	-. 117	April-----	. 503
September-----	. 064	May-----	. 100
October-----	. 113	September-November--	. 150
November-----	. 105	March-April-----	. 593
December-----	. 186	February-April-----	. 612
January-----	. 123	Annual, June to May--	. 491

<sup>1</sup> Value required for significance at 5-percent level=0.423; at 1-percent level=0.537.

Distribution of rainfall is one of the most obvious factors and one that can be readily studied. It has been well established that monthly precipitation varies widely and that periods of drought occur frequently. In 14 of the years under study there have been periods as long as 3 months in which the total rainfall has been less than 1.0 inch. Most, but not all, of these extremely dry periods have occurred during the winter months. The majority of them have been in years with below-average precipitation. A study of annual yields and precipitation indicates that, while there is a tendency for yields and annual precipitation to be correlated, there are enough reversals to make it evident that some other factor, or factors, is responsible in determining final yields.

Wheat occupies the land much longer than other annual crops. Therefore, it was thought that correlations between monthly precipitation during the period of seedbed preparation and through the growing season might give some information on the time of the year when rainfall was most likely to be critical (table 17).

The most important fact brought out by these correlations is that the rainfall in only one month, April, was significantly correlated with yield. The correlation coefficient was slightly higher than that

for the crop year as a whole. This relationship was improved where the rainfall in the months of February and March was also included. There is evidence that the total rainfall during the 3-month period, February through April, is extremely critical in determining the magnitude of wheat yield. In 34 years there was only one yield that was 5 bushels above average when February-through-April precipitation was below average. The above-normal winter precipitation during that year partly explains this exception. A severe rust infestation accounts in part for a second exception in which yields were low even though precipitation during February, March, and April was high.

The most obvious reason for dependence of wheat on the rainfall in February, March, and April is that adequate rainfall in the 3 months terminates the winter drought period and gives the crop a chance to start rapid growth under favorable conditions. Average precipitation for February and March is much lower than for April, and only April is likely to have rainfall enough to carry the crop well along toward maturity. Furthermore, a direct relationship exists between the level of correlation and the relative amount of rainfall in the 3 months. The reason for the low correlation coefficient between May rainfall and wheat yield is probably that by early May the crop either has enough water to carry it well along toward maturity or has suffered so badly that above-average rainfall in May is unable to produce a good yield.

Another equally striking feature was the lack of correlation between summer and fall precipitation and wheat yields. It has been generally accepted that adequate fall soil moisture is the best insurance of a crop the next year. Yet correlation coefficients between fall rainfall and yields are far below the level of significance. This can mean only that fall rainfall alone is not capable of producing a crop under the conditions at Woodward.

Additional information on the effect of rainfall on yield was obtained by separating the yields of early-prepared plots into two groups—one for years when wheat yields were below average and the other for years when yields were average or above (fig. 9). The greatest difference between the high and low yield groups was in the April rainfall. Important differences were also evident in the amount of rainfall in other spring months. Another difference occurs in September and October. Evidently, high rainfall in September and October, which provides adequate soil moisture at seeding time, is necessary for high yields, yet favorable fall soil moisture alone is not sufficient to carry a crop to maturity.

Correlations between relative humidity and wheat yields and between evaporation and wheat yields were also made. Observations of these climatic factors are for the 6 spring and summer months only, so the only correlations possible during the period when they would have affected wheat yields were for April, May, and the first part of June. Correlations for single months and for combinations of months were lower than those for April or for February-to-April precipitation. Relative humidity was more closely associated with yield than was evaporation; but no correlation for a single month

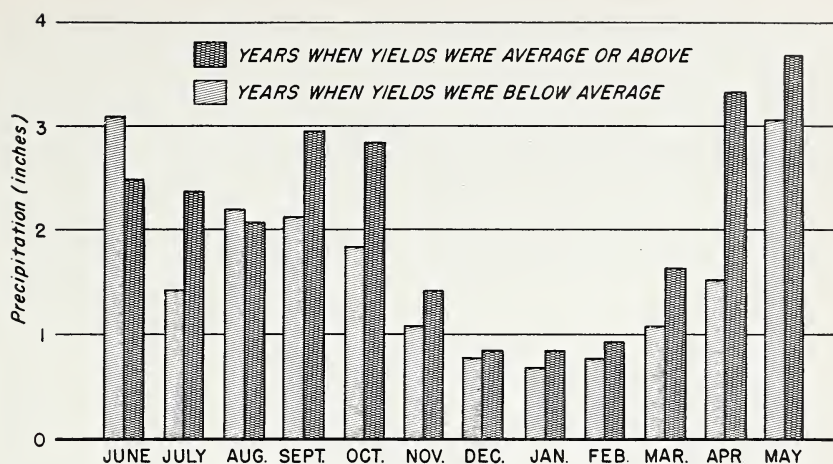


FIGURE 9.—Average precipitation by months in years when wheat yields were below average and in years when yields were average or above, Woodward, Okla., 1915-48.

was significant, and the combination of May and June was barely significant at the 5-percent level.

### WHEAT YIELDS AS RELATED TO SOIL MOISTURE

Since moisture is known to be one of the chief controlling factors in crop production, studies of the water content of the soil under different methods of cultivation have been made at intervals during the cropping season for many years. In addition, determinations of water content at harvest and seeding have been made on a large number of cultural treatments.

#### STORAGE OF WATER IN THE SOIL BETWEEN HARVEST AND SEEDING

Determinations of the change in water content of the soil between harvest and seeding were made for a 3-year period on a group of 14 plots in field B. This group involved 8 early-cultivated, 3 mid-season-cultivated, and 3 late-cultivated plots. During this period the early-prepared plots gained an average of 2.53 inches of water, the midseason-prepared gained 0.74 inch, and the late-prepared lost 0.52 inch. Differences in moisture storage of soils prepared with different tillage implements on the same date were not significant.

Moisture determinations were made for 5 years on the plots in the frequency-of-cultivation experiment. The average increase in the moisture content of the soil from different treatments between harvest and seeding was influenced appreciably by the number of cultivations during this period (table 18).

Cultivating at intervals of 2 weeks was not so effective in storing moisture as cultivating at monthly intervals. Lengthening the time between cultivations to 6 weeks reduced moisture storage much below

the level attained by monthly cultivations. Moisture storage in uncultivated land was extremely low.

TABLE 18.—*Average quantity of water stored between harvest and seeding on land one-wayed immediately after harvest and cultivated at different frequencies, Woodward, Okla., 1941-45*

Frequency of cultivation	Water stored between harvest and seeding	Percentage of total precipitation stored during period
	<i>Inches</i>	
At 2-week intervals-----	1. 71	24. 6
At monthly intervals-----	1. 88	27. 1
Once, about mid-August-----	1. 03	14. 8
No cultivation between one-waying and prepara- tion for seeding-----	. 63	9. 1

Even under the best method of cultivation, only a small percentage of the precipitation is stored. The highest quantity stored was only a little more than one-fourth of the precipitation for the period. The rest was lost chiefly by evaporation. This loss has not been reduced materially by any method of cultivation. Losses under less frequent cultivation were caused by weeds using the moisture as well as from evaporation. This additional loss by weeds can be controlled, and it must be to take full advantage of moisture resources.

#### SOIL-MOISTURE CONTENT AT THE TIME OF SEEDING WHEAT

The effect of the water content of the soil at seeding time is of prime interest. Yields are affected by practices such as early tillage, late tillage, and summer fallow. The question arises as to how much of this difference is caused by the tillage practice itself and how much can be assigned to differences in water storage as an indirect result of the various tillage practices. There is also the question of the extent to which the moisture content of the soil in the fall determines the final yield.

Correlations between available moisture in the soil at seeding time and the yield of grain on early-prepared land were computed from data from each field. Correlation coefficients were far below the level needed for significance. There was no evidence from soil moisture and yield data from plots receiving a given tillage practice over a number of years that the quantity of water in the soil at seeding time was the determinant of final yields.

Between varying contents of moisture in the soil the same year a different condition prevailed. Data from annual and average available moisture content at seeding time and yields for wheat (field B) and rye (field A) under three widely varied soil preparations were obtained (tables 19 and 20). Results in field A are for winter rye,

as the soil in the winter rye plots was more uniform than in the winter wheat plots and, therefore, permitted more accurate moisture determinations. The available water content was determined by subtracting the moisture content of the soil when dry to a growing crop from the actual water content as determined by soil-moisture sampling. The water content of the soil when dry to crops was the average of many determinations made when the crops were suffering for water.

TABLE 19.—*Annual available water content of the soil at seeding time under 3 cultural practices and yields of wheat<sup>1</sup> on field B, Woodward, Okla., 1934-48*

Year <sup>2</sup>	Available water at seeding time on—			Acre yield of wheat on—		
	Fallowed land	Early-prepared land	Late-prepared land	Fallowed land	Early-prepared land	Late-prepared land
	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>
1934-----	<sup>3</sup> 3. 89	<sup>3</sup> 1. 78	<sup>3</sup> 0. 21	18. 2	8. 0	2. 8
1935-----	<sup>3</sup> 3. 57	<sup>3</sup> 2. 84	<sup>3</sup> 2. 21	10. 7	6. 3	4. 8
1936-----	<sup>3</sup> 3. 83	<sup>3</sup> 2. 13	<sup>3</sup> 2. 00	19. 5	13. 0	10. 5
1937-----	5. 74	1. 65	1. 65	21. 8	5. 7	2. 3
1938-----	4. 47	2. 32	1. 25	41. 3	37. 2	30. 2
1939-----	5. 09	3. 59	. 28	18. 8	13. 0	7. 7
1940-----	2. 13	1. 89	. 11	10. 5	4. 8	. 7
1941-----	3. 03	1. 44	. 28	41. 5	37. 3	38. 7
1942-----	6. 32	6. 30	4. 51	31. 2	23. 5	23. 0
1943-----	6. 68	4. 08	3. 52	23. 5	14. 2	15. 8
1944-----	4. 64	3. 14	. 30	44. 0	29. 7	19. 7
1945-----	5. 35	2. 67	0	29. 5	24. 8	17. 0
1946-----	4. 73	3. 12	. 65	26. 0	16. 2	10. 7
1947-----	5. 18	2. 19	1. 25	20. 8	24. 7	20. 5
1948-----	2. 73	3. 85	. 06	18. 2	18. 8	10. 0
Average-----	4. 49	2. 87	1. 09	25. 2	18. 5	14. 3

<sup>1</sup> Correlation coefficients between available water—

In early-prepared land and yield----- 0. 069

In early-and-late preparation and yield----- . 512

In early-prepared land and fallow yield----- . 346

In late-prepared land and fallow yield----- . 409

Value required for significance:

At 5-percent level----- . 482

At 1-percent level----- . 606

<sup>2</sup> The year indicates the year in which the wheat crop was harvested.

<sup>3</sup> 3-foot totals. The rest of the totals are for 4 feet, and that depth usually covered the full depth of moisture penetration.

TABLE 20.—*Annual available water content of the soil at seeding time under 3 cultural practices and yields of rye,<sup>1</sup> field A, Woodward, Okla., 1921-46*

Year <sup>2</sup>	Available water at seeding time on—			Acre yield of rye on—		
	Fallowed land	Early-prepared land	Late-prepared land	Fallowed land	Early-prepared land	Late-prepared land
	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>
1921	4.53	3.63	2.06	19.1	20.7	10.9
1922	4.81	4.62	.27	25.2	19.3	7.9
1923	4.99	3.01	0	18.9	16.3	8.4
1924	5.09	5.24	5.07	7.9	8.8	8.4
1925	5.63	4.73	2.45	12.1	9.1	3.0
1926	4.39	1.94	.45	21.3	13.0	8.6
1927	6.15	6.04	4.94	12.0	12.9	4.5
1928	5.12	4.23	2.23	16.3	12.0	3.2
1929	5.44	3.12	.49	10.9	8.6	3.8
1930	5.54	4.86	1.83	16.3	13.6	3.9
1931	4.82	4.36	.94	16.3	14.5	5.9
1932	4.79	2.37	.39	19.3	12.9	6.4
1933	4.53	4.51	.62	6.1	6.3	0
1934	4.56	1.72	0	13.6	7.9	3.4
1935	4.49	2.32	.04	14.3	8.9	2.0
1936	4.69	2.45	.58	14.1	10.9	7.9
1937	5.80	3.16	2.06	20.7	12.3	6.4
1938	4.36	2.19	1.34	30.4	23.6	18.9
1939	3.55	3.29	.04	12.0	8.0	5.2
1940	2.97	.82	0	14.8	7.7	4.5
1941	3.95	1.18	0	27.3	22.7	16.6
1942	5.65	5.97	2.47	14.3	11.6	6.3
1943	5.03	3.65	1.76	13.8	15.5	6.4
1944	3.70	1.50	0	22.0	14.5	8.2
1945	4.92	3.70	0	14.3	10.9	5.5
1946	4.77	3.25	.47	13.8	10.9	4.5
Average	4.78	3.38	1.17	16.4	12.8	6.6

<sup>1</sup> Correlation coefficients between available water—

In early-prepared land and yield..... 0.246

In early- and late-prepared land and yield..... .379

In early-prepared land and fallow and yield..... .647

In late-prepared land and fallow and yield..... .494

Value required for significance:

At 5-percent level..... .374

At 1-percent level..... .478

<sup>2</sup> The year indicates the year in which the rye crop was harvested.

The dependence of the size of the yield on the water content at seeding is brought out by individual comparisons. In 118 of 123 possible comparisons, the soil with the higher water content at seeding time produced the higher yield. Differences were not always proportional to differences in water content, but conservation of water during the period before seeding usually resulted in more bushels of grain. On the average, during the 15 years that determinations were made on field B, a difference of an inch of stored water produced a difference of about 2.3 bushels of grain. During the 26-year period that determina-

tions were made on field A, a difference of an inch in stored water accounted for a difference of about 2.7 bushels of grain.

Correlations between differences in water storage in early- and on late-prepared land and differences in yields were significant on both fields. Correlations between differences in moisture content and differences in yield on fallowed land and early-prepared land were highly significant for the 26-year period in field A, but they fell below significance for the shorter period in field B. The correlations between fallowed land and early-prepared land in field A were by far the highest obtained and appeared to substantiate the opinion that yield differences between these two preparations were caused chiefly by differences in quantities of water stored at seeding time.

#### SOIL-MOISTURE FLUCTUATIONS DURING THE GROWING SEASON

Soil-moisture samples were taken at intervals during the growth of the crops for many years on field A and for a much shorter period on field B. These samples, particularly those taken in March or April, show why spring precipitation is so critical to wheat. In many years the available moisture content of the soil approached or reached depletion during early spring. There was usually some available water in the lower depths on early-prepared or on fallowed land, when the content of the late-prepared plots approached depletion. This enabled the crops on these plots to survive without damage for a longer period and to be in better condition to take advantage of more favorable conditions if they occurred later. The low water content in the spring furnishes a reasonable explanation of why rainfall for the early spring months is frequently so vital in crop production.

#### SOIL NITROGEN AND CARBON CHANGES AS RELATED TO CROPPING<sup>2</sup>

The plots in fields A and B were not sampled for nitrogen and carbon when the experiments were started. Certain groups of plots, however, were sampled when the experiments were terminated. It was recognized that the reduction from the original level could not be determined accurately, but it was thought that if major differences had resulted from different tillage methods or crop sequences they should be revealed by the present levels of nitrogen and carbon.

The continuous and alternate cropping systems of wheat and rye in field A offered the best comparisons. The plots were located side by side, and the different treatments were intermingled. The results appear to be clear-cut and decisive (table 21). The late-tilled plots were highest in nitrogen and carbon, the early-tilled plots were intermediate, and the alternately fallowed and cropped plots were lowest. That this difference was not caused by location was further brought out by individual comparisons. Every late-tilled plot was higher in nitrogen and carbon than any early-tilled plot. Every alternately fallowed and cropped plot was materially lower in nitrogen and carbon than the adjoining early-tilled plot. Thus, the higher yields on early over late tillage have not been obtained without a greater loss of soil nitrogen. The greater loss of nitrogen and carbon on alternately

<sup>2</sup> These analyses were made by H. V. Eck, agronomist, at Stillwater, Okla.

fallowed and cropped land further emphasizes the lack of value of this practice.

TABLE 21.—*Effect of cultural practices on the nitrogen and carbon content of the soil, fields A and B, Woodward, Okla., 1933-48*

Field and cultural practice	Plots	Nitrogen and carbon content at—			
		0 to 6 inches		6 to 12 inches	
		N	C	N	C
<i>Field A</i>					
Wheat or rye, continuous:	<i>Number</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Late-tilled-----	4	0. 057	0. 61	0. 053	0. 54
Early-tilled-----	8	. 041	. 42	. 047	. 49
Alternately cropped and fallowed-----	4	. 030	. 30	. 035	. 35
<i>Field B</i>					
Rotations:					
Vetch for hay; wheat-----	2	. 047	. 48	. 058	. 57
Vetch for green manure; wheat-----	2	. 056	. 56	. 057	. 52
Austrian Winter peas for hay; wheat-----	2	. 052	. 48	. 050	. 51
Austrian Winter peas for green manure; wheat-----	2	. 052	. 51	. 052	. 48
Cowpeas for hay; wheat-----	2	. 047	. 47	. 055	. 53
Cowpeas for green manure; wheat-----	2	. 044	. 49	. 047	. 52
Wheat—continuous, early-tilled-----	8	. 053	. 56	. 057	. 58

The rotations in field B, where legume crops were either plowed under for green manure or harvested for hay, in comparison with land continuously cropped to wheat appeared to offer the greatest opportunity for differences in nitrogen and carbon to develop. The average dry hay yields for Austrian Winter peas were 1,382 pounds; for hairy vetch, 2,158 pounds; and for cowpeas, 1,742 pounds. It was thought that plowing under the quantities of green matter every other year represented by these hay yields would result in very evident differences in the content of soil nitrogen and carbon.

Results were disappointing. Only the vetch showed any benefit from plowing under the green-manure crop rather than harvesting it. The legume-rotation plots as a whole were slightly lower in nitrogen and carbon than the continuously cropped early-tilled wheat plots. Since plowing under of the quantities of green matter grown in these rotations has resulted in little benefit, there seems to be no great possibility of soil improvement through annual legumes. It seems worthy of mention, however, that after the field was returned to grass, the grass following vetch and Austrian Winter peas plowed under was for several years noticeably greener than on other plots.

## DISCUSSION

Wheat has been a dependable crop at the Southern Great Plains Field Station. Complete failures have been rare, and yields of less than 10 bushels to the acre under good cultural practices are the exception. Nevertheless, in most years the crop suffers some reduction in yield from drought; therefore, moisture conservation is the most important consideration in wheat production.

No implement appears to be markedly superior to any other for the first tillage operation after harvest, provided that it is equally efficient in killing weeds. Choice of implements can be determined by the cost of operation and the surface condition after their use. The objective of tillage during the period between harvest and seeding is to have at seeding a firm seedbed, well supplied with moisture and with sufficient crop residue on the surface to help control wind erosion should the wheat fail to make an adequate fall cover. This can usually be attained by using two or more implements rather than by the exclusive use of any one implement. The best assurance of adequate moisture is early initial preparation and control of weed or volunteer wheat growth until seeding time. In some years there is little or no rainfall to store between harvest and seeding, but in all years early tillage is needed to reduce loss of water already in the soil and to take full advantage of years with substantial summer rainfall. A firm seedbed is usually attained by a shallow tillage operation in advance of seeding.

Delaying tillage of stubble land until the middle of August results in a material reduction in average yield, regardless of the nature of the tillage or of subsequent cultivations. The reduction in yield from midseason tillage as compared to tillage soon after harvest was about 5 bushels to the acre, a very substantial reduction that can and should be avoided.

Delaying initial tillage until shortly before seeding wastes the rain that falls during the summer and gives the crop a poor start, from which it seldom fully recovers, regardless of conditions after seeding. Average yields resulting from late tillage were very low—approximately 9 bushels less than yields on land tilled soon after harvest.

Wheat is not well adapted to rotation with other crops in this area. Sorghums, which are second in importance to wheat, grow until late fall and leave a seedbed deficient in moisture for wheat. Yields of wheat after sorghums were only a little higher than those of late-prepared continuous wheat and as much as 8 bushels lower than those of continuous wheat prepared early. Wheat does well following corn or cowpeas, but these crops are of little importance in the area. Yields after cotton were intermediate between those after sorghums and after corn.

The detrimental effect of sorghums is not overcome by growing these crops in wide-spaced rows. The yield of wheat is much higher than that of wheat following sorghums in conventional-width rows, but the total yield of wheat and sorghum in such a rotation is lower than that of an equal area of land planted to wheat under early preparation. There is one condition where growing of sorghums in wide-spaced rows might be desirable. This is where wheat has failed and it is

necessary to grow some cash crop, but it is desirable to plant all the land to wheat in the fall. Wide-spaced row crops are a means of producing a small cash crop while providing a seedbed fairly favorable to the planting of wheat.

Summer fallow, a practice of so much importance in many dry-land areas, is not well adapted to climatic and soil conditions like those at Woodward. The acre yield of wheat was increased by about one-third by the use of fallow. This means that only two-thirds as much wheat would be grown on land alternately fallowed and cropped to wheat as on the same area of land planted to wheat each year under good methods of cultivation. Fallow has not added greatly to the reliability of production. When conditions were severe enough to cause low yields or failure on early-prepared land, yields on fallowed land were also likely to be low. The chief effect of fallow in the Woodward area is to increase yields in years of fair to high production rather than to prevent failures.

Fallow in the area should be used chiefly as an emergency measure. Where wheat fails, fallowing is likely to be more economical than planting to some other crop that leaves a seedbed deficient in moisture. Fallowing gets sorghum land in condition for wheat. Whether it can be profitably used for this purpose is a matter of economics. More wheat can be grown in 2 years by growing two successive crops of wheat after sorghum than by fallowing the first year and producing a single crop of wheat on fallow. The greater cost of growing the two crops of wheat, however, may more than offset the difference in production.

Green-manure crops have not been effective in bringing yields above the levels attained on fallowed land. The winter-growing legumes used for green manure—hairy vetch and Austrian Winter peas—have caused a more vigorous fall growth of wheat, yet no consistent increases in final grain yields have resulted. There is a possibility, however, that the time may come when soil-building legumes will be necessary to continued good production. Hairy vetch offers the greatest possibility of fulfilling this need, but soil analyses showed little benefit from plowing under eight crops in a 16-year period.

Commercial fertilizers are likely to occupy an increasingly important place in wheat production, as supplies of nitrogen and available phosphorus in the soil are reduced by continued cultivation. It is not uncommon to note nutrient-deficiency symptoms on crops early in the season, but in most years the extent of this deficiency is not reflected in final yields because lack of moisture is the controlling factor.

Applications of a combination of nitrogen and phosphorus can be expected to result in little increase in yield in some years, low to moderate increases in many years, and very high increases in a few years. There will probably be more years when fertilizers will not pay for themselves than when they will, yet the very high returns for some years makes fertilizer application profitable on the average. To be sure of getting the occasional high returns the grower has to take his chances and apply fertilizer in all years.

The years of high response to fertilizers have been years when spring moisture conditions have been favorable throughout May.

Spring moisture conditions furnish some indications of whether fertilizer application may be profitable. Decision on whether to fertilize cannot safely be delayed until spring, however, because best returns have been obtained only when part of the fertilizer was applied in the fall. Whether the time will come when the farmer can anticipate the moisture conditions early enough to regulate nitrogen application and thus make them fully effective is a questionable point. Moderate fall applications of fertilizer each year appear to be the best means of making sure to obtain the high responses that are realized occasionally. The average profit will depend on the frequency with which such high yields occur.

The experimental results given might indicate that wheat is adapted only to a one-crop system of farming. This is not true. Most farmers in the area practice mixed farming, and the production of other crops such as grain or forage sorghums is a necessity. This does not mean that the farmer necessarily need balance his acreage. Where wheat is the principal crop in the farming system, the greater the amount of the wheat that can be grown following wheat, the better. When crops other than wheat are grown, their effect on wheat and the economies of production should guide the farmer in fitting them together in a cropping system.

## SUMMARY

This circular reports results of tillage, rotation, fertility, and time of seeding experiments with winter wheat at the Southern Great Plains Field Station, Woodward, Okla., for the years 1915-49. Experiments were conducted on moderately fertile sandy and silt loam soils.

Annual precipitation in this area averages 23.76 inches, but it has varied from less than 15 to more than 41 inches during the period covered. The frost-free period averages about 200 days.

Time of tillage affects wheat yields more than any other single factor that is under control. Initial tillage starting shortly after harvest increased yields more than any method of delayed tillage.

Type of tillage implements, if they controlled weeds, was relatively unimportant as far as yields were concerned.

Differences caused by plowing every year as compared with plowing every 2 to 5 years alternating with cheaper and faster tillage methods were unimportant.

Soil should be tilled frequently enough to prevent weeds from becoming well established and exhausting subsurface moisture.

Fallow is unimportant as a cropping practice in the Woodward area. Therefore, differences in methods of maintaining fallow were likewise of little consequence.

A delay in seeding of a month beyond normal seeding dates decreased yields.

Growing wheat in rotation with grain sorghums reduced yields significantly.

Legume green-manure or hay crops grown alternately with wheat did not increase yields above those from alternate crop and fallow.

Stable manure applied in a 4-year rotation increased wheat yields over a similar rotation with no manure and to a lesser extent over those with cowpea or rye green manure. Differences increased toward the end of the period.

Nitrogen and phosphorus fertilizers used together increased yields more than either element used alone. Yields were increased sufficiently by the combination to be profitable on the average, but in only a few years.

Effect of precipitation at various periods of the crop season is discussed. Precipitation for April is only month that gives a significant correlation coefficient with yield.

Moisture data show differences in soil-moisture storage for different dates and frequencies of cultivation and show desirability of storing as much moisture as possible.

# APPENDIX

TABLE 22.—*Monthly and annual precipitation at the Southern Great Plains Field Station, Woodward, Okla., 1915-48*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1915.....	1.17	3.44	1.45	6.53	5.29	2.43	3.14	3.62	5.74	2.36	0.55	0.06	35.78
1916.....	1.50	.03	.82	1.78	1.70	10.26	.00	1.02	2.34	1.71	.75	.60	22.51
1917.....	1.20	.20	.10	1.58	1.03	1.37	1.13	6.65	2.72	.05	.67	.01	15.71
1918.....	1.60	.29	2.09	2.22	4.00	1.91	.73	1.35	1.24	3.35	1.53	2.92	23.23
1919.....	.06	1.53	1.94	4.10	4.29	2.22	1.35	1.87	.63	1.85	2.37	( <sup>1</sup> )	22.21
1920.....	1.03	.07	.61	1.06	3.40	1.29	4.69	3.00	5.01	2.55	1.32	1.53	25.56
1921.....	2.22	.61	1.33	1.80	1.91	5.78	2.50	5.11	2.94	.01	.00	.11	24.32
1922.....	1.02	.96	5.08	2.97	3.95	.18	1.07	2.31	2.83	.74	1.15	.00	22.26
1923.....	( <sup>1</sup> )	.06	1.86	2.32	8.11	4.20	.69	.39	9.33	11.99	.89	.84	40.68
1924.....	.03	.81	2.96	3.14	.78	1.46	3.07	3.40	3.22	2.29	1.90	1.48	24.54
1925.....	.14	.12	.40	3.18	1.34	2.06	2.34	.79	2.44	.70	2.04	.46	16.01
1926.....	.54	.11	1.89	1.70	2.23	3.51	5.18	1.79	3.37	6.09	1.09	1.34	28.84
1927.....	.41	.68	1.22	2.20	.52	4.30	6.89	3.93	.77	.21	.09	.23	21.45
1928.....	.01	1.63	.97	1.58	6.69	3.74	1.42	.35	.81	4.54	3.78	1.03	26.55
1929.....	.92	.20	2.04	.77	3.41	.58	3.15	2.10	4.45	1.89	2.83	.12	22.46
1930.....	.56	.02	.18	2.58	7.78	2.93	.28	1.42	1.06	2.56	1.71	.49	21.57
1931.....	.26	.94	4.31	2.23	3.44	2.69	1.16	1.53	2.86	1.55	.73	.53	27.23
1932.....	1.06	.82	.46	3.36	2.33	9.21	.34	4.98	.41	.64	.01	1.25	24.87
1933.....	.07	.52	.48	2.42	1.25	.10	1.87	4.78	1.72	.86	.52	.20	14.79
1934.....	.83	.50	1.71	2.08	2.25	4.69	.09	1.97	2.50	1.07	1.93	.93	20.55
1935.....	.86	.79	.90	.01	7.17	1.61	.30	.95	1.56	2.32	2.29	.35	19.11
1936.....	.46	.09	( <sup>1</sup> )	.60	5.21	2.37	.23	.54	3.53	1.68	.02	.86	15.59
1937.....	.66	.38	1.78	.48	2.37	1.68	.51	2.28	3.91	3.65	.03	.40	18.13
1938.....	.03	2.21	1.86	4.77	8.33	4.55	3.10	1.45	2.12	.20	.49	.19	29.30
1939.....	2.84	1.01	1.59	4.38	1.66	3.97	2.58	.85	( <sup>1</sup> )	.09	.44	.83	20.24
1940.....	.93	1.58	.18	2.27	1.46	1.26	2.54	1.16	1.84	.69	3.43	.75	18.09
1941.....	2.17	2.00	1.57	3.66	8.46	5.72	2.00	1.92	2.84	9.66	.64	.58	41.22
1942.....	.26	.82	.77	3.54	2.01	2.92	1.92	2.93	3.31	4.56	.07	1.11	24.22
1943.....	.01	.15	.54	1.31	4.84	1.83	2.27	1.39	.81	1.49	.36	3.52	18.52
1944.....	1.04	1.22	1.69	6.83	1.93	1.38	4.38	1.73	1.91	4.01	1.29	1.79	29.20
1945.....	1.18	.76	1.17	3.37	.87	2.15	1.70	3.45	4.51	.21	( <sup>1</sup> )	.20	19.57
1946.....	.32	2.25	1.65	.03	2.44	1.81	.29	2.41	6.34	5.55	2.44	1.31	26.84
1947.....	.51	.06	2.55	4.48	6.44	1.72	1.72	.39	.06	.03	1.38	1.78	21.12
1948.....	.09	3.39	1.43	1.48	.93	4.82	1.54	8.18	.47	1.73	1.28	.09	25.43
Average.....	.74	.89	1.46	2.55	3.52	3.02	1.95	2.41	2.64	2.44	1.32	.82	23.76

<sup>1</sup> Trace.

TABLE 23.—*Monthly and seasonal evaporation, Southern Great Plains Field Station, Woodward, Okla., 1915-48*

Year	April	May	June	July	August	September	Seasonal, April- September
	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
1915.....	5.98	6.73	6.64	10.04	6.52	5.76	41.67
1916.....	5.93	10.09	8.25	10.67	11.11	7.88	53.93
1917.....	6.79	6.98	11.54	11.72	7.59	5.26	49.88
1918.....	4.97	9.27	8.67	10.08	11.00	5.79	49.78
1919.....	6.00	5.36	6.37	10.69	9.31	7.60	45.33
1920.....	7.70	6.45	10.41	9.79	6.87	7.27	48.49
1921.....	6.92	8.04	7.28	9.32	10.29	8.75	50.60
1922.....	7.92	8.91	10.59	11.03	11.53	7.84	57.82
1923.....	5.50	6.34	8.42	10.70	11.64	6.50	49.10
1924.....	6.32	6.42	10.49	9.09	9.49	7.41	49.22
1925.....	6.85	7.17	11.78	9.87	8.71	6.57	50.95
1926.....	4.77	7.34	10.38	9.70	8.61	6.97	47.77
1927.....	5.60	8.16	9.25	9.81	6.32	6.96	46.10
1928.....	7.32	7.00	7.06	9.84	10.02	9.24	50.48
1929.....	6.64	5.33	9.83	10.37	11.03	7.62	50.82
1930.....	7.05	7.31	9.96	12.96	11.71	8.84	57.83
1931.....	4.64	6.88	10.66	10.83	9.08	10.90	52.99
1932.....	6.63	8.32	7.62	12.23	10.71	6.63	52.14
1933.....	7.74	8.92	12.90	11.39	8.05	8.28	57.28
1934.....	6.25	8.76	12.14	15.78	11.64	7.13	61.70
1935.....	6.39	5.59	7.90	12.11	11.05	7.09	50.13
1936.....	7.28	6.91	10.96	13.01	13.19	5.86	57.21
1937.....	6.62	8.30	9.29	13.48	10.83	7.17	55.69
1938.....	4.12	5.97	8.19	9.44	12.20	7.04	46.96
1939.....	6.39	7.88	9.48	11.79	10.71	10.90	57.15
1940.....	6.46	8.15	10.28	13.14	9.62	8.03	55.68
1941.....	5.51	6.62	7.13	8.73	8.24	6.95	43.18
1942.....	5.32	9.04	8.45	11.43	8.51	6.95	49.70
1943.....	7.11	6.14	9.89	9.90	12.03	7.30	52.37
1944.....	5.02	7.61	10.40	9.23	9.93	7.14	49.33
1945.....	4.30	7.99	7.58	9.42	9.61	8.58	47.48
1946.....	7.17	7.93	10.69	12.22	9.12	6.14	53.27
1947.....	4.31	6.39	9.22	10.23	11.34	9.72	51.22
1948.....	7.71	8.29	8.88	10.17	7.55	7.56	50.16
Average.....	6.21	7.43	9.37	10.89	9.86	7.52	51.28

TABLE 24.—*Monthly and annual mean temperatures at the Southern Great Plains Field Station, Woodward, Okla., 1915-48*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual average
	°F. (1)	°F. (1)	°F. (1)	°F.	°F.	°F. (1)	°F.	°F.	°F. (1)	°F. (1)	°F. (1)	°F. (1)	°F.
1915.....				60	62	73	78	72	(1)	(1)	(1)	(1)	-----
1916.....				54	69	73	82	82	70	59	45	30	-----
1917.....	33	36	46	54	61	78	84	76	72	54	51	30	56
1918.....	24	42	54	51	71	81	81	84	66	56	44	36	58
1919.....	35	37	47	57	62	71	80	83	74	57	41	33	56
1920.....	34	39	49	53	66	77	80	74	72	62	42	37	57
1921.....	39	40	52	57	69	75	81	81	76	63	47	39	60
1922.....	32	38	46	57	68	78	82	83	75	60	48	38	59
1923.....	43	34	43	57	64	76	83	82	73	54	48	38	58
1924.....	32	39	37	57	61	80	78	82	68	62	49	27	56
1925.....	31	43	53	63	67	82	82	79	73	51	46	36	59
1926.....	34	45	44	52	68	77	79	80	71	62	44	35	58
1927.....	36	41	45	60	70	75	80	75	72	64	50	31	58
1928.....	39	39	49	54	67	71	81	80	72	62	45	38	58
1929.....	29	27	49	61	64	77	81	83	70	59	37	38	56
1930.....	20	49	45	63	66	78	84	83	76	57	48	36	59
1931.....	39	44	40	54	63	80	83	78	80	63	48	41	59
1932.....	33	46	41	60	68	75	84	80	71	58	44	29	57
1933.....	42	35	49	57	69	83	84	79	78	61	50	41	61
1934.....	37	38	45	59	70	82	89	85	68	64	50	37	60
1935.....	38	42	53	56	62	74	85	84	70	59	43	37	59
1936.....	32	28	51	59	69	80	87	88	72	57	46	40	59
1937.....	25	37	43	58	71	77	86	86	73	59	43	35	58
1938.....	38	40	53	56	66	77	81	85	74	66	44	38	60
1939.....	41	32	50	57	70	78	84	82	77	65	46	42	60
1940.....	19	39	49	57	68	77	84	79	73	66	43	41	58
1941.....	36	36	42	57	69	73	80	80	72	59	48	39	58
1942.....	34	36	47	59	67	76	82	78	69	59	48	36	58
1943.....	35	43	41	60	62	78	83	85	70	57	46	33	58
1944.....	35	40	43	53	68	80	80	81	71	61	48	35	58
1945.....	36	38	51	53	65	72	80	81	71	61	49	33	58
1946.....	36	45	54	64	65	78	85	81	71	61	46	42	61
1947.....	36	35	42	55	64	76	81	85	77	67	42	37	58
1948.....	32	32	40	65	69	78	81	78	73	60	43	39	58
Average.....	34	39	47	57	66	77	82	81	72	60	46	36	58

1 No record.

TABLE 25.—Average monthly and annual wind velocity at the Southern Great Plains Field Station, Woodward, Okla., 1915-48

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual average
	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>	<i>M.p.h.</i>
1915.....	(1)	(1)	(1)	9.4	8.0	7.7	7.5	4.1	(1)	(1)	(1)	(1)	-----
1916.....	(1)	(1)	(1)	9.2	9.1	8.3	5.7	7.4	8.2	8.0	8.9	7.9	-----
1917.....	6.6	8.2	10.4	11.5	9.0	9.4	7.5	5.1	4.4	7.0	6.6	7.2	7.1
1918.....	7.0	9.5	8.4	7.8	11.1	6.2	6.4	6.3	5.4	5.3	6.5	7.7	7.3
1919.....	5.6	9.7	8.8	9.5	6.1	5.1	6.8	6.1	7.4	6.9	7.1	6.3	7.1
1920.....	6.7	5.8	11.7	11.2	7.6	9.9	6.1	5.0	6.6	7.3	6.8	9.0	7.8
1921.....	7.5	7.4	9.9	9.1	6.8	5.4	6.1	5.8	8.8	9.0	5.9	7.0	7.4
1922.....	7.9	8.3	7.2	8.1	6.9	5.7	6.0	6.3	6.4	6.4	7.6	8.4	7.1
1923.....	7.2	7.2	11.4	8.4	6.4	7.4	5.8	6.6	6.7	5.0	5.1	6.9	7.0
1924.....	8.4	8.7	7.0	9.1	6.0	7.7	6.5	6.5	6.2	6.2	6.4	6.4	7.1
1925.....	5.6	7.0	9.2	8.1	6.8	7.9	5.5	5.1	5.5	5.4	5.7	7.0	6.6
1926.....	6.4	7.6	7.7	6.8	7.0	7.2	5.4	5.4	8.1	5.6	8.4	6.6	6.9
1927.....	7.1	8.0	9.4	7.6	8.3	7.2	6.0	4.5	6.8	7.0	7.0	8.4	7.3
1928.....	7.8	8.6	9.2	10.4	6.1	6.5	7.1	6.8	7.9	7.2	8.3	7.9	7.8
1929.....	8.0	7.3	9.0	10.6	7.5	7.9	7.0	6.3	7.3	5.4	6.4	6.0	7.4
1930.....	6.9	8.6	8.8	7.9	7.3	7.4	7.4	6.6	7.6	7.2	8.0	6.1	7.5
1931.....	6.6	6.9	9.6	7.9	7.0	6.8	6.1	5.9	9.4	6.9	6.5	7.6	7.3
1932.....	7.7	7.9	8.7	9.5	7.1	5.4	8.0	8.2	5.5	7.2	7.2	6.8	7.4
1933.....	8.3	8.3	9.7	9.1	8.0	8.2	6.0	6.2	7.9	5.3	7.2	6.2	7.5
1934.....	6.9	7.4	9.0	7.5	7.0	7.7	9.0	6.9	8.4	6.8	7.4	6.5	7.5
1935.....	7.8	9.0	9.9	9.1	4.7	6.8	7.1	7.1	7.3	7.7	7.7	6.3	7.5
1936.....	7.2	7.3	9.7	8.2	4.5	6.1	7.0	7.6	7.0	7.6	7.4	7.9	7.3
1937.....	7.9	9.9	8.5	8.6	7.1	6.2	8.4	7.3	5.9	6.3	6.8	5.8	7.4
1938.....	8.0	8.8	10.2	8.8	6.2	4.7	5.5	7.9	5.0	6.5	7.5	6.0	7.1
1939.....	8.4	7.5	8.0	9.6	6.5	7.6	7.1	7.1	7.7	8.4	5.1	6.8	7.5
1940.....	5.1	8.4	8.8	9.0	7.4	8.1	9.5	5.8	6.9	8.1	7.7	7.0	7.7
1941.....	6.5	6.5	7.7	9.3	8.0	6.9	5.1	5.3	7.7	5.8	5.4	7.3	6.8
1942.....	6.6	7.8	8.7	9.6	10.0	7.7	7.4	5.9	7.3	6.2	8.3	5.9	7.6
1943.....	7.8	8.4	9.0	8.2	8.3	8.9	6.5	7.7	5.9	5.7	6.2	5.8	7.4
1944.....	6.4	7.7	9.3	9.2	7.8	9.8	6.1	7.0	7.0	4.6	6.5	6.3	7.3
1945.....	6.1	7.0	9.0	8.4	8.2	6.8	5.9	3.7	8.2	6.0	6.8	6.5	6.9
1946.....	7.2	9.7	10.1	7.4	7.4	9.5	6.9	6.2	7.0	9.3	7.4	7.1	7.9
1947.....	6.8	7.3	7.9	8.7	6.4	7.8	5.9	6.4	7.6	5.8	6.6	4.6	6.8
1948.....	3.6	4.3	6.5	6.4	3.9	3.2	3.2	3.3	4.4	5.0	6.4	5.9	4.7
Average.....	7.0	7.9	9.0	8.8	7.2	7.2	6.6	6.2	7.0	6.6	6.9	6.8	7.3

1 No record.

TABLE 26.—*Comparative yields of wheat (field A) in bushels per acre on land continuously cropped, using different tillage methods, and on land alternately cropped and fallowed, 1915–48*

Year	Acre yields when land is—						
	Late-plowed <sup>1</sup>	Late-disked or one-wayed <sup>1</sup>	Early-plowed 8-inches deep <sup>2</sup>	Early-plowed 4-inches deep <sup>2</sup>	Early-disked or one-wayed <sup>2</sup>	Early-listed <sup>2</sup>	Alternately cropped and fallowed
	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>
1915	16.0		27.6			23.8	31.8
1916	2.2		4.5			4.2	2.8
1917	2.2		7.2			4.3	11.5
1918	0		6.0			6.0	9.8
1919	13.7		12.2			15.8	13.7
1920	9.8		9.8			19.5	12.5
1921	23.8		28.3			29.5	32.8
1922	13.3	8.2	27.2	35.3	34.5	28.5	34.5
1923	17.0	12.2	22.3	9.8	14.0	14.5	35.8
1924	13.7	15.8	10.3	22.3	17.8	13.5	7.5
1925	5.5	8.7	18.5	20.2	16.7	18.8	20.8
1926	12.5	12.8	20.8	16.7	20.7	20.5	29.7
1927	5.8	6.8	13.0	13.2	14.8	14.0	13.0
1928	5.3	4.2	19.5	21.8	16.8	14.0	19.7
1929	6.5	6.5	12.3	19.5	13.0	10.5	11.8
1930	6.8	6.2	20.2	21.7	14.7	16.3	22.2
1931	11.8	16.7	23.8	25.7	22.3	19.2	27.5
1932	13.0	18.2	20.5	23.8	20.8	21.3	26.7
1933	1.7	2.2	9.5	11.7	10.2	9.3	8.2
1934	4.8	5.3	15.0	7.7	11.7	13.7	23.3
1935	4.5	4.8	11.8	9.8	9.2	9.5	20.0
1936	12.0	11.0	19.3	18.7	14.3	17.2	20.8
1937	10.3	7.5	19.8	14.8	17.0	19.0	27.5
1938	27.5	26.0	29.7	37.2	33.8	31.0	39.8
1939	8.5	6.7	16.8	19.5	18.8	18.3	19.8
1940	3.7	4.2	8.8	8.3	10.7	5.3	13.7
1941	31.3	27.7	30.0	35.5	33.3	21.7	35.8
1942	9.7	11.5	13.5	21.8	15.5	16.2	18.0
1943	9.3	11.7	17.0	19.2	17.5	19.0	18.3
1944	13.2	18.2	23.5	30.8	27.2	23.7	31.3
1945	13.0	17.5	16.8	22.0	20.5	19.8	26.2
1946	10.3	14.0	19.3	18.0	20.2	17.8	20.8
1947	15.2	16.8	10.8	17.3	14.2	10.8	17.5
1948	8.5	11.0	11.0	17.0	13.7	10.2	9.7
Average 1922–48 <sup>3</sup>	10.9	11.6	17.8	20.0	18.3	16.8	22.0
Average 1915–48	10.7		17.0			16.4	21.0

<sup>1</sup> Average date for late tillage, September 29.<sup>2</sup> Average date for early tillage, July 6.<sup>3</sup> L. S. D. at 5-percent level compared with early-fall plowing at 8-inch depth=2.0 bu.

TABLE 27.—Yearly yields of continuous wheat under 23 different cultural practices compared with yearly yields on uniform plots with uniform treatments the same years, Woodward, Okla., 1933-48

Tillage practice (a) for variable treatment year and (b) for uniform plot, same year	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Average
Early (early July):																	
(a) Plowed 8 inches	11.7	16.3	8.5	16.2	16.8	36.0	15.5	7.0	34.5	28.0	18.0	29.2	18.8	20.3	12.0	17.8	19.2
(b) One-wayed	12.2	8.5	9.6	15.3	14.3	31.2	16.7	6.0	38.3	21.8	20.7	27.8	22.0	18.7	10.2	16.2	18.0
(a) Plowed 8 inches, straw burned	12.5	13.7	6.5	17.0	13.8	32.8	15.0	11.2	33.7	28.8	20.5	26.5	21.8	20.8	13.7	18.8	19.1
(b) One-wayed	11.7	11.8	16.3	15.5	13.5	29.5	17.3	9.7	36.7	22.2	19.2	23.5	20.8	17.3	15.2	14.2	18.0
(a) Plowed 8 inches	12.7	14.0	6.7	20.7	15.3	37.5	15.8	7.0	34.3	28.0	17.3	32.0	18.2	22.3	11.2	22.7	19.7
(b) One-wayed	13.3	11.7	12.8	15.3	13.7	31.5	17.0	10.2	36.5	21.0	22.5	18.8	27.2	18.2	22.2	13.0	19.1
(a) One-wayed, kept clean with one-way	10.0	11.2	6.7	16.8	13.3	43.0	15.0	4.2	34.2	27.0	17.0	29.8	16.0	20.2	11.2	22.0	18.6
(b) Plowed 8 inches	13.5	13.5	6.5	15.0	8.7	32.7	17.8	7.0	41.7	19.0	23.5	23.3	21.0	15.3	21.5	13.5	18.6
(a) One-wayed, plowed 8 inches Aug. 15.	10.2	13.7	6.0	20.3	13.3	39.0	15.7	3.3	33.8	29.0	17.0	35.3	17.5	21.8	10.8	22.2	19.3
(b) One-wayed	14.0	13.8	6.0	15.5	12.7	33.8	18.2	10.8	37.8	20.7	22.8	26.3	27.0	18.7	21.0	13.3	19.5
(a) Plowed 4 inches	10.8	11.5	6.0	14.5	15.5	32.8	13.5	9.0	29.2	22.7	15.3	27.5	14.3	18.8	12.8	15.7	16.9
(b) Plowed 8 inches	12.2	11.5	5.5	14.5	12.5	28.7	15.7	7.3	36.7	19.8	19.5	21.2	22.0	16.7	18.0	14.5	17.3
(a) One-wayed, listed Aug. 15.	10.2	16.7	11.0	18.2	17.5	35.8	14.2	5.8	25.0	25.5	13.7	28.7	16.0	18.5	9.5	16.8	17.7
(b) One-wayed	13.7	17.0	9.2	15.2	14.3	25.7	17.2	11.2	35.7	17.5	24.3	23.0	23.7	17.7	20.0	16.0	18.5
(a) Bush listed	10.5	16.7	7.8	14.7	12.8	29.8	15.2	3.7	31.7	21.3	18.8	24.3	19.3	20.3	12.7	16.8	17.5
(b) One-wayed	11.2	15.0	9.3	14.7	16.0	32.7	17.0	11.0	33.2	20.3	17.8	26.3	22.0	17.8	13.2	15.2	18.3
(a) Plowed 8 inches, harvested with binder	10.8	8.0	7.3	13.5	9.3	40.3	14.2	3.8	33.8	25.2	15.3	40.8	17.7	15.5	11.0	20.0	17.9
(b) One-wayed	12.7	5.7	7.8	13.7	8.3	36.7	16.3	6.0	36.8	23.7	18.2	29.5	27.0	18.7	26.0	13.2	18.8
(a) Disked, kept clean with disk	10.3	12.5	5.8	16.2	14.3	41.3	15.2	6.3	31.8	22.8	14.3	30.5	16.3	19.5	10.7	15.2	17.7
(b) Plowed 8 inches	11.8	12.7	6.5	14.0	10.7	34.2	16.0	7.8	40.2	20.8	21.5	22.2	21.0	17.7	23.7	15.7	18.7
(a) Listed, leveled	12.0	16.7	5.8	14.2	13.0	34.7	16.0	4.2	34.0	23.5	17.7	25.7	19.7	21.2	14.7	17.5	18.3
(b) One-wayed	12.0	15.0	8.0	16.3	13.8	35.3	17.8	12.2	36.2	22.7	20.0	27.8	21.5	19.7	14.0	17.0	19.4
(a) Plowed 8 inches, topdressed in winter	11.7	9.8	6.2	14.0	8.3	37.7	14.8	7.0	41.0	29.5	20.5	19.5	22.0	20.2	21.3	18.8	18.9
(b) One-wayed	10.3	9.8	6.5	12.0	8.0	41.0	16.2	8.0	43.2	27.3	19.8	32.2	26.2	20.8	21.5	19.2	20.1
(a) Plowed 8 inches, planted month late	7.3	16.2	14.0	18.7	16.5	24.3	12.8	11.2	11.5	13.2	14.5	20.0	16.5	19.5	6.5	17.2	15.0
(b) One-wayed	12.3	12.2	10.7	14.3	15.7	25.3	16.2	7.5	35.0	17.5	21.5	22.3	23.3	18.2	13.5	8.5	17.1
(a) Plowed 4 inches, harvested with binder	11.0	11.0	7.0	13.7	12.5	42.2	17.5	3.3	35.0	22.3	17.7	29.0	13.2	21.5	13.0	21.5	18.2
(b) Plowed 8 inches	12.3	10.0	7.5	16.7	9.8	36.2	16.3	8.8	41.0	23.3	23.2	31.3	25.3	21.0	21.0	22.3	20.4
(a) One-wayed, harvested with binder	9.7	10.8	5.8	15.8	13.2	44.5	16.2	4.2	36.2	23.5	15.2	34.2	17.7	18.0	12.7	17.2	18.4
(b) Plowed 8 inches	13.8	11.8	9.5	15.7	11.8	37.2	18.7	8.5	41.8	24.5	26.2	28.7	31.2	20.0	23.7	17.2	21.3

Midseason (Aug. 15): <sup>1</sup>		9.8	10.5	2.7	14.8	7.2	34.5	17.5	8.5	35.5	20.3	17.7	17.0	18.5	17.7	17.2	12.8	16.4
(a) One-wayed.....	12.8	15.2	8.7	14.3	11.2	8.5	38.5	16.7	9.8	39.8	27.7	23.3	33.3	26.8	23.0	20.2	20.5	21.4
(b) Plowed 8 inches.....	7.3	11.5	2.8	11.3	8.5	30.8	30.8	15.3	3.7	23.5	19.2	10.2	18.0	7.7	16.7	7.3	11.8	12.9
(a) Plowed 8 inches.....	12.0	14.7	8.2	15.3	11.2	31.3	31.3	16.0	8.5	36.8	18.5	20.2	22.8	24.0	20.2	15.8	10.7	17.9
(b) One-wayed.....	8.2	5.8	3.7	12.3	10.7	35.8	35.8	13.5	3.3	26.7	22.7	11.2	17.7	9.6	15.8	9.8	13.5	13.8
(a) Plowed 4 inches.....	15.7	12.3	8.2	14.8	6.3	32.5	32.5	18.7	7.8	38.8	19.2	25.7	25.3	29.7	18.7	24.7	13.5	19.5
(b) Plowed 8 inches.....	7.0	12.8	2.7	11.8	14.2	29.2	29.2	11.2	4.2	18.2	16.3	8.5	11.3	7.2	13.3	7.3	10.7	11.6
(a) Listed.....	13.5	16.3	7.0	14.8	13.3	26.3	26.3	16.5	9.8	36.8	17.0	20.8	23.5	23.5	21.5	14.3	8.8	17.7
Late (Sept. 15 or later): <sup>1</sup>		1.8	8.7	5.8	9.7	12.8	31.5	11.3	3.7	17.5	11.3	10.5	10.7	7.5	7.7	8.8	9.3	10.5
(a) One-wayed.....	12.8	16.3	10.3	16.2	12.2	17.0	17.0	17.0	11.5	38.3	23.0	22.5	29.0	25.3	24.2	21.8	15.3	19.5
(b) Plowed 8 inches.....	3.5	7.7	4.5	9.7	12.3	19.2	19.2	10.7	4.0	24.3	11.5	10.7	9.8	7.7	7.5	10.5	7.5	10.1
(a) Plowed 4 inches.....	11.7	14.5	8.0	14.8	11.3	31.8	31.8	15.3	10.3	38.0	22.2	21.2	30.2	25.7	24.0	21.5	14.8	19.7
(b) Plowed 8 inches.....	5.0	5.8	3.0	9.3	9.3	17.8	17.8	14.8	5.0	23.5	15.2	16.0	11.0	10.5	10.8	9.8	11.5	11.1
(a) Disked, straw burned.....	12.2	17.8	9.5	16.0	11.7	35.8	35.8	16.8	10.5	37.7	23.8	22.7	31.0	27.2	26.8	16.8	20.2	21.0
(b) Plowed 8 inches.....	1.5	8.5	8.2	9.2	9.8	14.2	14.2	3.7	5.0	9.0	9.7	5.3	11.3	11.0	21.2	9.7	16.2	9.6
(a) One-wayed and planted month late <sup>2</sup> .....	14.0	15.3	11.0	15.3	15.3	25.7	25.7	18.2	8.8	38.0	20.0	26.0	25.7	30.2	19.7	19.2	11.3	19.6
(b) Plowed 8 inches.....	2.8	8.0	6.5	5.0	9.7	16.2	16.2	8.7	8.5	10.5	11.2	6.5	11.8	6.8	9.3	7.7	5.7	8.4
(a) No cultivation, seed stubbled-in.....	15.3	13.8	11.0	16.7	15.7	30.0	30.0	18.0	9.8	39.7	21.8	26.7	26.8	29.5	21.3	27.5	16.5	21.2
(b) Plowed 8 inches.....																		

<sup>1</sup> Time applies to variable treatment (a) plots only. All (b) plots were plowed or one-wayed early.  
 Changed to early Noble-cultivated, 1945-48, latter yields included.

TABLE 28.—*Yields of wheat on land one-wayed uniformly after harvest and cultivated at seeding, but cultivated at different frequencies after the initial tillage operation, field B, Woodward, Okla., 1942-48*

Frequency of cultivation after harvest	Acre yield in—							
	1942	1943	1944	1945	1946	1947	1948	Average <sup>1</sup>
	<i>Bu.</i>	<i>Bu.</i>	<i>Bu.</i>	<i>Bu.</i>	<i>Bu.</i> <sup>®</sup>	<i>Bu.</i>	<i>Bu.</i>	<i>Bu.</i>
At 2-week intervals.....	20.7	14.3	25.8	22.0	15.7	15.7	16.0	18.6
At monthly intervals.....	24.3	16.7	24.2	23.3	15.3	18.3	19.3	20.2
Once about mid-August.....	21.7	15.8	22.7	18.3	13.3	18.3	17.7	18.3
No cultivation between initial one-waying and seeding.....	20.3	15.8	21.0	14.0	10.7	16.3	16.3	16.3
Average.....	21.8	15.7	23.4	19.4	13.8	17.2	17.3	18.4

<sup>1</sup> L. S. D. from no cultivation between harvest and preparation for seeding at the 5-percent level=1.9 bu.

TABLE 29.—*Annual yields the first and second crops of wheat after fallow in a group of 3-year rotations*<sup>1</sup>

	Acre yield in—											Average		Differ- ence				
	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945		1946	1947	1948	1st year after fal- low
Preparation for fallow preceding first crop of wheat (a), and preparation for second crop of wheat (b) <sup>2</sup>																		
(a) Spring-plowed 8 inches	Bu. 12.7	Bu. 14.8	Bu. 11.2	Bu. 25.8	Bu. 19.5	Bu. 42.3	Bu. 20.0	Bu. 10.7	Bu. 45.7	Bu. 28.7	Bu. 22.3	Bu. 41.0	Bu. 34.5	Bu. 25.5	Bu. 24.5	Bu. 28.2	Bu. 25.5	Bu. 18.9
(b) One-wayed, straw burned	9.5	3.0	7.0	15.7	9.2	36.8	16.0	10.7	37.2	32.2	20.5	30.3	21.3	22.5	15.8	14.3	18.9	6.6
(a) Spring plowed 8 inches	12.2	15.2	8.8	21.0	17.8	36.5	19.0	12.7	38.2	26.8	19.5	47.6	27.7	21.8	17.3	27.2	23.1	18.5
(b) One-wayed, harvested with binder	9.3	7.5	7.2	16.3	13.0	35.5	15.8	11.5	33.8	22.5	19.0	30.8	18.7	22.0	16.8	16.3	18.5	4.6
(a) Spring-plowed 8 inches	10.5	17.5	9.7	23.3	21.8	38.7	19.3	15.0	40.5	28.8	20.8	53.8	30.5	25.2	24.8	24.7	25.3	7.2
(b) One-wayed	9.2	4.3	8.2	15.3	12.0	35.5	16.2	13.5	34.5	21.5	20.7	29.8	19.8	19.5	15.3	14.5	18.1	18.1
(a) Plowed 8 inches soon after wheat harvest	11.3	15.7	10.3	22.5	22.7	40.8	18.7	15.3	39.3	27.2	24.7	44.2	32.3	27.5	27.3	20.2	25.0	18.8
(b) One-wayed	10.7	8.2	8.5	17.0	17.2	37.7	18.5	13.0	36.2	22.2	17.2	29.5	20.7	14.8	15.3	14.8	18.8	6.2
(a) Basin-listed soon after wheat harvest	10.7	20.0	11.7	20.2	22.2	38.3	17.8	8.7	35.8	25.2	23.2	45.3	33.2	26.2	29.2	18.8	24.2	18.9
(b) One-wayed	11.7	11.7	9.3	20.5	17.7	35.2	17.5	13.2	33.0	24.0	18.5	26.7	21.2	13.7	12.5	15.7	18.9	5.3
(a) Basin-listed soon after wheat harvest	10.3	15.8	12.2	22.2	22.7	40.2	19.0	9.2	36.5	26.8	24.7	47.2	32.3	27.2	30.5	19.5	24.8	19.0
(b) One-wayed	11.8	10.3	7.5	20.5	18.5	34.3	19.3	14.2	31.7	24.3	13.3	27.5	27.0	12.5	13.0	17.5	19.0	5.8
(a) Listed soon after wheat harvest	12.5	19.3	12.0	25.8	21.3	41.8	21.5	7.7	39.3	30.0	24.8	47.8	36.8	26.7	30.5	20.8	26.2	19.1
(b) One-wayed	12.0	8.8	8.8	18.7	20.5	35.5	18.8	13.7	32.2	26.5	16.3	28.5	23.5	13.3	12.2	15.8	19.1	7.1
(a) Spring plowed 8 inches	11.3	21.2	13.0	23.0	22.8	43.8	20.0	12.5	40.2	31.3	24.7	50.2	33.8	26.8	33.7	24.5	27.1	20.1
(b) One-wayed	10.7	12.3	9.8	18.0	20.2	32.5	18.7	13.3	36.2	28.2	19.7	27.0	23.3	15.2	16.8	19.2	20.1	7.0

<sup>1</sup> The rotations were fallow, wheat, wheat.<sup>2</sup> All one-wayed for second crop of wheat was done early.

TABLE 30.—*Annual yields of wheat in 2-year rotations, in which wheat follows a legume crop that is harvested for hay or is plowed under for green manure, field B, Woodward, Okla., 1933-48*

Year	Acre yield of wheat after—					
	Austrian Winter peas as—		Hairy vetch as—		Cowpeas as—	
	Hay crop	Green manure	Hay crop	Green manure	Hay crop	Green manure
	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>
1933.....	14.0	13.3	9.5	11.2	5.8	11.0
1934.....	22.2	22.3	21.3	22.8	19.2	19.7
1935.....	10.3	8.8	7.3	10.5	4.7	5.7
1936.....	21.8	23.2	21.2	24.2	16.0	18.8
1937.....	22.7	22.2	19.8	18.8	14.8	14.2
1938.....	41.2	43.2	40.2	44.2	29.3	46.2
1939.....	20.2	20.2	19.0	19.7	14.0	18.2
1940.....	18.8	11.8	15.2	18.3	5.2	8.5
1941.....	37.8	36.2	41.3	41.8	35.3	35.5
1942.....	24.5	24.2	22.3	20.2	23.5	24.3
1943.....	25.5	16.8	26.3	10.5	18.5	23.3
1944.....	44.2	39.0	37.2	35.3	34.7	44.2
1945.....	31.2	22.8	29.2	22.0	28.5	29.0
1946.....	28.5	24.5	28.7	17.3	25.2	30.3
1947.....	32.6	44.5	34.5	43.8	18.7	37.2
1948.....	21.5	22.7	21.5	20.0	17.7	19.5
Average.....	26.1	24.7	24.7	23.8	19.4	24.1



